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The Journal of the Iron and Steel Institute.

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INDEX.

DANKS'S ROTARY PUDDLING FURNACE.

At the General Meeting, held at Dudley, in August, 1871, a paper was read by Mr. Samuel Danks, describing his Patent Rotary Puddling Furnace, as it was then in operation at several iron-works in the United States. Acting upon suggestions made after this paper had been discussed, the Puddling Committee undertook to send a duly qualified Commission to investigate the merits of Mr. Danks's puddling apparatus. Immediately after the meeting, this matter was taken in hand. The Committee selected the following gentlemen to form the Commission :—Mr. J. A. Jones, Middlesbrough; Mr. G. J. Snelus, Dowlais; and Mr. J. Lester, Wolverhampton; and arrangements were forthwith made with them to carry out the enquiry—in the case of Mr. Snelus, the Dowlais Iron Company kindly allowing that gentleman to serve upon the Commission. The Committee considered that it was highly desirable for the Commissioners to take out sufficient materials from this country to thoroughly test the apparatus, so that their report might afford data from which to judge how far the American machine might be used with the pig iron and fettling available in this country. Forty tons of pig iron (selected from Dowlais, Coneygree, Butterley, and Cleveland) were sent to America, together with the following varieties of fettling materials —Marbella, Spanish, Lisbon and Purple ores, Pottery Mine, and Ilmenite. The Committee prepared detailed instructions for the guidance of the Commissioners. When the proposal to appoint a Commission was first made, Mr. Danks undertook to accompany the gentlemen selected, and guaranteed that the necessary facilities should be afforded at the Cincinnati Railway Iron Works for making the requisite experiments,—these works being partly

owned by Messrs. Worthington and Butler, the joint holders, with Mr. Danks, of his patents. Mr. Danks went with the Commissioners, and, as will be seen from the report of these gentlemen, they have had full opportunities of investigating the working of the puddling apparatus, not only at Cincinnati, but also in other parts of the United States, where it is in operation. The Commissioners sailed from Liverpool early in October. They wrote their joint general report at Washington, on December 12th, and it was ready for the consideration of the Committee on the 12th January. The Committee, feeling that the members are desirous of having the report of the Commissioners as early as possible, have decided to issue at once what has been received, though the chemical analyses of a number of selected samples cannot be ready for some time, and though it is hoped that supplementary reports will be made by each member of the Commission, dealing fully with the scientific, practical, and commercial aspects of the enquiry. The samples of English iron, brought back by the Commissioners, will be exhibited at the annual meeting, to be held in London, on March 19th, and following days; and arrangements will be made for testing these samples at the same time. It is hoped that the analyses, and supplementary reports, will also be laid before the annual meeting.

The investigation has necessarily involved the expenditure of a considerable sum, to meet which the Puddling Committee made a special appeal to the iron trade of the whole country. This has already been very liberally responded to. A full statement of the contributions and expenses, in connection with this fund, will be presented to the next general meeting.

The Committee have arranged with Mr. Danks, that the royalty to be paid in Great Britain shall not exceed two shillings per ton on machine-made puddled iron.

The Report of the Commissioners is appended:—

REPORT OF THE COMMISSION,

APPOINTED BY THE

PUDDLING COMMITTEE OF THE IRON & STEEL INSTITUTE,

TO INVESTIGATE THE WORKING OF

DANKS'S ROTARY PUDDLING MACHINE

IN AMERICA.

TO THE PUDDLING COMMITTEE OF THE IRON AND STEEL INSTITUTE.

GENTLEMEN,—In accordance with the instructions received from you, we have made an investigation into the working of the Danks's rotary puddling furnace in America, and we beg to report as follows:—

We caused the whole of the material sent out by you to be forwarded to the Cincinnati Railway Iron Works.

We propose to make the report in the order laid down for our guidance in your printed form of instructions. Proceeding accordingly, we begin with your first instruction.

1. "A general description of the furnace and accessories."

Danks's rotary puddling furnace consists of a horizontal revolving chamber, which chamber intersects the fire-grate and an elbow flue leading to the uptake of the chimney. The shape of

this chamber, when fettled, partakes of an ellipse. The two ends are brought in by means of two cast iron rings forming a portion of the outer framework or structure. This structure rests by its periphery on four cast iron friction wheels, fixed in framings, and it revolves between the fixed grate or fire-place and the elbow joint before referred to. The furnace is driven by a pair of vertical reversible trunk engines, the spur wheel on the crank shaft being geared direct into a toothed wheel forming the periphery of the rotary furnace. The rotary portion referred to is formed of several cast iron segments, which are held together by means of two cast iron rings before named, one at each end slipping over the ends of the said castings. The inner shape of the castings which form the chamber is a series of dovetails running longitudinally, which are for the purpose of mechanically holding in the fix or fettling.

The fire-grate is similar in construction to that of an ordinary furnace, the bridge being built in the end of the grate. It is provided with a pair of folding doors, which, when closed, and dabbed with clay, form a closed chamber. Air is provided by means of a fan, or blower—a portion is taken horizontally above the fuel, but the bulk is driven in underneath the bars.

The elbow-joint, above referred to, forms the flue end of the whole apparatus, and it makes a short turn at right angles leading to the uptake of the chimney. The object of having this elbow connection is to allow of its being readily removed, in order to get at the interior of the revolving chamber. The piece, or connection, is suspended to a way above by means of a chain attached to a pinion, which pinion runs into a rack above. A pulley and chain are fixed on the same axis as the pinion, by means of which the apparatus is removed and re-placed at will.

The two rings, forming the ends of the revolving chamber, are provided with water pipes, cast in them, by which means they are kept cool. The fire-bridge and chamber end of the elbow-joint are also kept cool in like manner.

This description is intended only as a very general one. For details of furnace, see drawings attached, and also Mr. Danks's paper, printed in the Institute JOURNAL, No. 4, Vol. II., 1871.

The tools, by means of which the furnace is charged, and the product removed, consist, firstly, of a charging pan. This pan is capable of holding the full charge of pig iron, together with the

squeezer slag, and is as in Fig. 1. The pan is of scoop shape, and

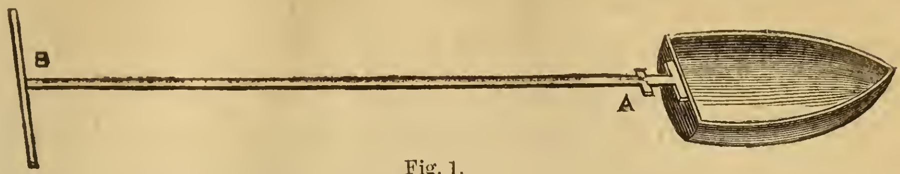

Fig. 1.

the length of the handle is about 10 feet. It is raised from the ground by means of a fixed jib crane (Fig. 8), one being erected for the use of each furnace. The hook in the chain is attached at A—the man in charge seizing the handle B. It is raised, swung round, and the contents deposited in the revolving chamber.

Secondly, the charge is withdrawn by aid of a fork, which is suspended by means of the before-mentioned crane, and is in shape as in Fig. 2. When the charge is ready to be withdrawn, the fork is inserted on edge in the chamber. The machine is then caused to move about one-third of a revolution, and the ball is

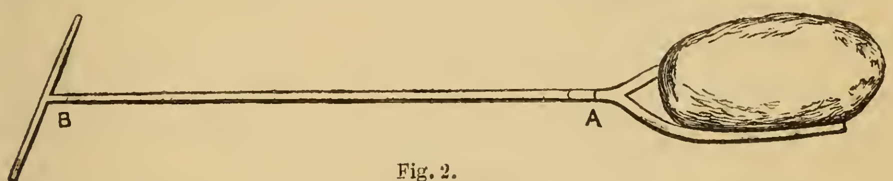

Fig. 2.

deposited between the prongs of the fork. The fork is then raised slightly by means of the crane, the chain of which is hooked on at A, the man in charge manipulating the handle B, and it is withdrawn from the furnace, the jib of the crane swinging round for this purpose.

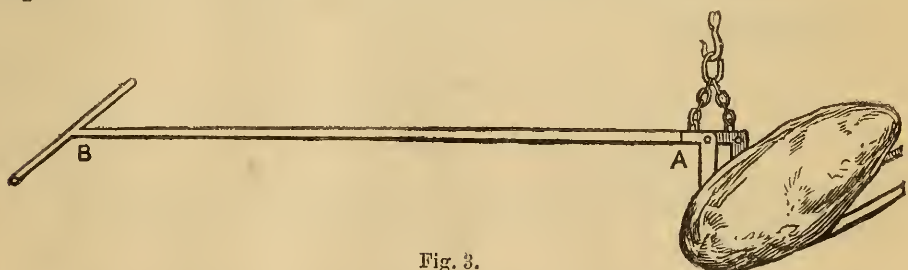

Fig. 3.

Thirdly, a receiving-fork, suspended to a way above leading to the squeezer, is now brought into proximity to the fork on which the ball is deposited, and, by turning the handles of the latter, the ball is thrown across the prongs of the receiving fork. (Fig. 3.)

Two men regulate the handle B, and the ball is run along the way suspended at A, and tipped into the squeezer.

The squeezer (Fig. 4), by which the ball is manipulated, is known as Winslow's, and, with additions and improvements made by Mr. Danks, is specially constructed for a heavy mass of iron, such as is produced in the rotary furnace.

It consists, firstly, of two corrugated rollers of about 4 feet long in the barrel and about 18 inches diameter. These are horizontally placed, occupying one plane, and the journals fixed in strong frames. These rollers are made to move in one direction at the rate of about from 15 to 20 revolutions per minute. Above these rollers is geared a large eccentric or cam, the periphery of which moves at the same rate of speed as the circumference of the two rollers before named. The shape of the cam is as in sketch. At the side of the squeezer frame is a horizontal steam hammer, which hammers the end of the bloom up as it is being rotated. When the bloom is sufficiently squeezed, which is done in two revolutions of the cam, it is removed from its position by means of a neat lever arrangement, and rolled upon the floor.

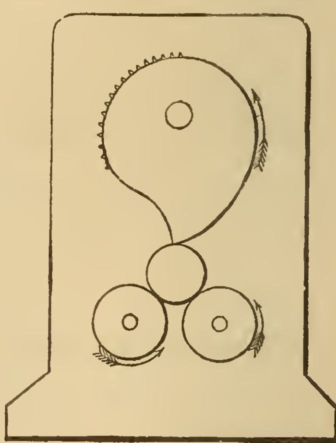

Fig. 4.

It is now seized by a pair of tongs (Fig. 5), and lifted, by

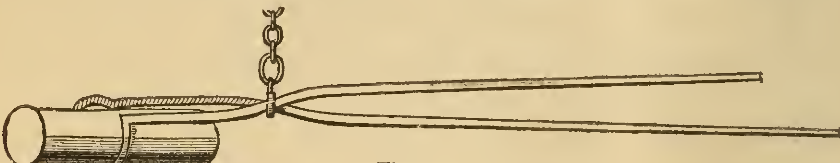

Fig. 5.

means of a crane, used for charging and drawing at the reheating

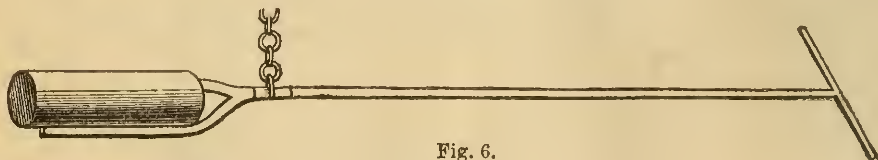

Fig. 6.

furnace, and placed on a fork, by which means the bloom is charged and drawn. (Fig. 6).

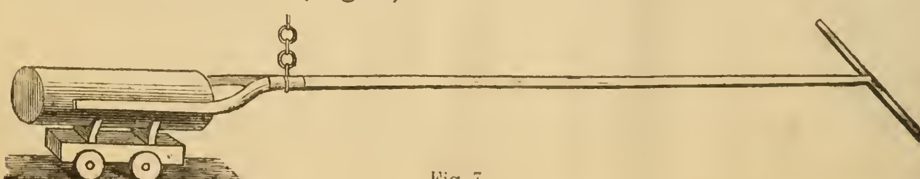

Fig. 7.

When drawn, it is placed on a bogie (Fig. 7), and taken to the rolls.

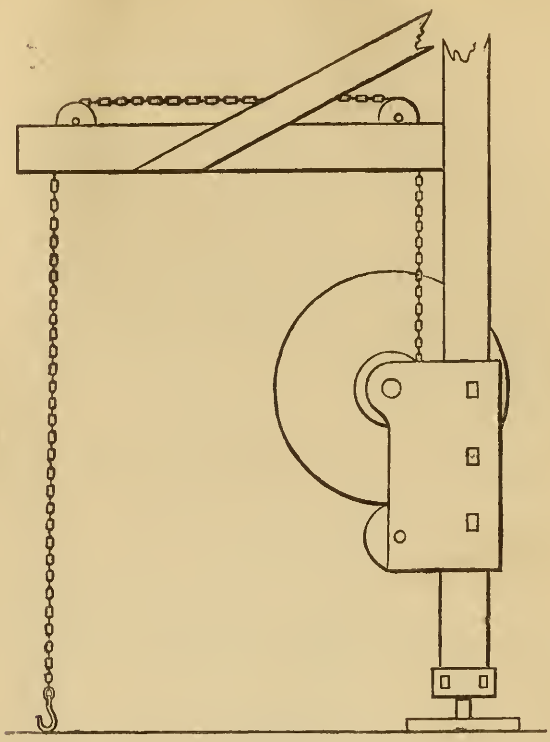

Fig. 8.

2. "The mode of fettling the furnace; full particulars of materials used; quantity of each kind; how long the fettling stands in the furnace; the amount of repairs done to lining between the charges. This should include a considerable number of charges, in order to get a proper average, and full particulars of each should be given."

See Diaries Nos. 1, 2, and 3; and Statements Nos. 4 and 5.

3. "The quantity of fuel used; quantity consumed per ton of puddled bar produced for periods extending over a whole week's work of each furnace under examination."

See Statements Nos. 4, 6, and 7.

4. "Details of each stage of the process. Time occupied in fettling; time in melting iron; time in working before cinder is tapped off, and revolutions of machine at each change of speed; time of working from tapping off cinder to balling up; time in preparing for next charge."

See Diaries Nos. 1, 2, and 3.

5. "Quality of iron produced. Samples of each kind of iron

worked should be kept for analysis, and samples of puddled bar produced from each charge containing English materials should also be taken, and carefully marked, so as to admit of easy identification."

With regard to the quality of the iron produced, we are aware that this is a most important part of our enquiry, and we have, therefore, undertaken to bring back to England samples of iron produced at each stage of the process—from a bloom, weighing between 600 and 700 lbs., down to wire rods and other finished iron—as well as samples of the intermediate stages. You will thus have the opportunity of testing the various irons, and forming your own conclusions thereon. With regard to the impression made upon the minds of the Commissioners, we beg to say that we are satisfied, on the whole, that the quality of the iron produced is materially improved by this process.

On fracturing the squeezed bloom, we found it presented an open spongy mass, as though it had not received sufficient compression, and also presenting tokens of the presence of a quantity of cinder. There can be no doubt that this is the case. On the bloom, however, being reheated and rolled into a bar, it parts freely with its cinder, and in the fracture of the bar we were not able to detect the presence of more of it than is found in any other puddled bar. The bar in fracture presented the appearance of that of an ordinary puddled bar.

In the various blooms which we fractured, we searched for pieces of unreduced fettling, and we discovered several pieces in one bloom, but only in one. The others seemed in the fracture to be free from it. We had anticipated that this ugly fracture would have presented itself more freely, but we are compelled to admit that in the subsequent working of the iron it did not bear out our anticipations.

It is our duty to remark here that the machinery for squeezing and rolling at the Cincinnati Works, was too weak to deal effectively with such a heavy mass of iron as 600 pounds in weight. The size of the train is 18 inches, and it certainly would not have taken a hammered bloom of 12 inches diameter without risk of breakage. In order to meet this contingency, the squeezer but partially did its duty; and to the rolls, after a re-heat of the blooms, was delegated the work of removing a large portion of the cinder. The gear

attached to the squeezer was also light, and that tool had also to be humoured. With stronger squeezing and rolling machinery, no doubt the cinder can be more effectively removed on its first manipulation after coming from the puddling furnace; but we do not expect that the sponginess in the bloom, to which we have before alluded, will have disappeared by that improvement. It may be necessary, in order to get a close and compact fracture in the bloom, to resort to hammering; but on this point we cannot at present offer any decided opinion. It may be, and it is probable, that the sponginess, of which we have spoken, is no detriment to the quality of the iron, after having been worked in the subsequent processes. Whether the reheating from the squeezer will be found to be indispensable is a matter we cannot well determine now. On rolling off a few pieces, the result was not satisfactory. It may have been due, and probably was, to the somewhat imperfect manner in which the bloom had been squeezed. Samples at various stages have been taken for your inspection.

6. "Particulars of quantity and quality of slag run off from each charge."

See Statements Nos. 4 and 5; and Diaries Nos. 1, 2, and 3.

7. "The weight of iron charged in each heat should be carefully recorded. Also particulars of weight of hammer scale, or other materials put in with the iron. Your attention is specially directed to the statements that a greater weight of puddled iron is brought out of the furnace than is put in as pig iron."

See Statements Nos. 1, 2, 3, 10, and 11.

8. "Looking at the number of furnaces at work, you are requested to report particulars as to the percentage that are kept in regular operation each shift, with the view of affording data for estimating the amount of work to be expected from a whole forge fitted up on Danks's system."

On referring to Statement No. 10, you will perceive that of nine furnaces which were lit for work, eight worked more or less continuously throughout the week.

9. "Particulars as to the number of men employed in connection with each furnace and with squeezer; class of workmen, whether ordinary iron workers or mechanics."

There are two men who directly control the working of the furnace, viz., a forehand and underhand. There is, secondly, a

labourer between two furnaces, whose duty it is to take away the slag, to assist in charging the furnace, and to work the crane in the manipulation of the tools. Thirdly, there are two men who run the balls from the furnaces to the squeezer by means of the fork and way as before described. These two men also remove the bloom from the squeezer, lift, and deposit it on the charging fork for the reheating furnace. An additional labourer works the horizontal hammer.

About one-half of the men, at the rotary furnaces, were old puddlers—the other half were young men, who had had nothing whatever to do with puddling. One of them, a fitter, was the best puddler at the works.

10. "Royalty paid per ton in America."

So far as we could ascertain, the royalty paid in America is one dollar per ton of puddled bar.

11. "Particulars as to the number of works where the apparatus is in operation, and number of furnaces at each place; opinions of American practical men on the machine; details of classes of finished iron for which the machine-made puddled iron is used; whether used alone, or mixed with scrap or old rails, when being converted into finished iron."

At the Cincinnati Railway Iron Works, there are *nine* rotary puddling furnaces erected, and one in course of erection. Eight furnaces are kept in constant work, and one used as a reserve; so that, should a breakage occur, the men can be transferred to the idle furnace. There are no other puddling furnaces in the forge.

At the Roane Iron Works, Chattanooga, Tennessee, *nine* furnaces are erected: seven were at work during our visit. Both the above works have the Winslow squeezer, with Danks's improvements.

At the Indianapolis Rolling Mills, Indiana, two furnaces were completed and "initial" lined, two others nearly completed, and six more in course of preparation. A Winslow squeezer was nearly finished.

Jones, Laughlin, and Co., at Pittsburgh, have one furnace, which they worked for about three months (up to the hot weather of last summer), making iron for small sections, but having no squeezer the results were not altogether satisfactory to them. The yields were good, as will be seen from the annexed statement, No. 11, which they kindly allowed us to copy from their books.

Mr. Jones expressed the opinion that, with the squeezer, the results would have been improved. We had several heats worked in the machine, and treated under the hammer, but it was quite evident that the appliances at their command did not enable them to deal with a large ball in a satisfactory manner. For details of the heats we saw worked, see Statement No. 11.

At the Fort Pitt Foundry, Pittsburgh, which we visited, they were making the castings for ten furnaces, and a squeezer, for Graff, Bennett, & Co., who, we understand, were guided in their decision by the recommendation of Jones, Laughlin, & Co.

At New Albany, near Louisville, one furnace was at work for a short period, but the works were burnt down some time ago, and, although rebuilt, the rotary furnace has not been put in operation again.

We found the general opinion of American practical men upon the subject to be, that the machine was a success. Some few modified their statement by stating that they "thought it would do very well for rails, but would not make sufficiently clean and regular iron for small sections." The evident reason for this caution, on their part, is to be found in the following statement. The only class of finished product for which the machine-made puddled iron has been used, at works when the complete apparatus is erected, is *rails*. That the machine is quite capable of making good iron for other purposes is evident from the results of our experiments at the Globe Works, Cincinnati, where English and Welsh iron was rolled into various small sections, plates, and sheets. For details of these experiments, see Statement No. 8. The machine-puddled iron is generally piled with old rails, but in our experiments very good rails were made from piles of puddled bar alone. A few rails were subsequently made from Welsh white iron (crystal and bar pig), with No. 2 iron for head and flange, and puddled bar for the middle of the pile.

12. "Particulars as to the production of steel blooms in the rotary furnace."

Three puddled steel blooms were made. Two of these were rolled into rails, which, on fracture, exhibited fine crystalline heads, but the flange in each case was finely fibrous. The third was hammered and broken, but did not show a good steel fracture. The attempt to make puddled steel was not very satisfactory, but

this is, no doubt, to be attributed to the fact of the men not being accustomed to work puddled steel.

13. "Particulars as to loss on the machine-made iron in the secondary stages of the manufacture."

See Statement No. 8.

14. "How far the squeezer is an essential feature of the plan, and whether the machine-made iron can be manipulated under the ordinary steam hammer."

We do not think the squeezer is an essential feature in the working of machine-made iron. If a means can be devised for the handling of such a heavy mass of iron as a ball weighing from 600 to 1,000 lbs. under a steam hammer, and getting it worked in reasonable time, it will do probably so far as the quality of the iron is concerned somewhat better than the squeezer; but obviously the squeezer is a handy, expeditious, and simple tool by which to manipulate the ball.

15. "Particulars of the heat at which the furnace is worked at different stages of the process."

See Diaries Nos. 1, 2, and 3.

"It is requested that a detailed daily report be made during the whole time of your investigation, embracing full particulars of everything connected with the working of the rotary furnaces that comes under your notice."

By referring to Diaries and Statements, you will perceive that your instructions have been attended to.

"The commercial aspects of the matter under enquiry should also receive careful attention, and you should make such comparisons, and obtain such facts as will enable you to report upon the commercial bearings of the machine puddling apparatus, and upon the relative cost of puddling by the machines as against the cost of hand puddling."

We are of opinion that we have collected facts sufficiently to enable the Committee to form a decided opinion upon the commercial bearings of this invention. With coal, fettling, and repairs given, and yield of puddled bar from pig, and quantity turned out in a given time, it will not be difficult for any one engaged in the manufacture of iron to determine the bearings of this matter. The machines we experimented on are in an early stage of the rotary process of puddling, and immense strides can rapidly be made in

developing the process, which strides will materially affect the commercial bearings of the matter as it now stands. At present we are agreed that the rotary furnace as it now is offers advantages commercially over the old process.

If necessary, a further report will be provided by the members of the Commission separately, on the chemical, commercial, and practical aspects of rotary puddling.

"Samples of the American pig iron and fettling materials used should be brought away."

Attended to.

"You are requested to dispose of the iron you do not require on the best terms you can obtain on the spot."

None to dispose of.

"After completing your investigation, the Committee wish you to agree upon a joint report, giving the particulars you have recorded from time to time in appendices, under the various headings given above. It will be also open to each one of you to make an independent report upon any matters that cannot be included in the general statement."

"You are requested to make your enquiry a complete record of all *facts* bearing upon the subject, but your report will have to embody the opinions you deduce from a careful consideration of those facts."

This has been fully attended to.

In closing their report, the Commissioners desire to return their thanks to all those gentlemen in America who have so kindly assisted them in their undertaking, and particularly Messrs. Hewitt & Cooper, Messrs. Perkins, Livingstone, & Post (the Dowlais Company's agents), who very kindly undertook all the shipping arrangements in regard to the material taken to and sent from New York, the proprietors of the Chattanooga Works, Mr. Blair, Messrs. Jones, Laughlin, & Co., of Pittsburgh, and Mr. Kinsey, of Cincinnati.

Signed this 12th day of December, 1871, at the city of Washington, U.S. of America.

GEO. J. SNELUS.
JOHN A. JONES.
JOHN LESTER

DIARY OF No. 4 FURNACE, ENDING Nov. 13.

Showing when Samples were taken for Analysis.

MONDAY, November 6th, 1871.

Selected the various kinds of pig iron, and arranged to put an initial lining into No. 4 revolving furnace, and to fettle No. 6 furnace with English ore upon an old initial lining of Iron Mountain ore.

Time.	
9· a.m.	Commenced lining 1st third of barrel with Iron Mountain ore.
2· p.m.	„ 2nd „ „ Blue Billy.
5·30	„ 3rd „ „ Bilbao.
8·	Finished initial lining.

NOTE.—Each portion was dried by a wood fire as soon as it was finished.

TUESDAY, November 7th.

A.M.	
2·	Commenced firing to dry and heat up initial lining.
5·30	Grate bars cleaned and fire urged.
6·45	Commenced glazing with hammer slag.
7·30	Initial lining completely glazed.
7·40	1st lot of pottery mine and scrap, to form the inner lining, thrown in. This was *melted* to form a bath into which the *lumps* are thrown. This operation is termed "fixing," and the material used a " fix."
	Fire urged in order to melt fix rapidly.
8·	Furnace set revolving slowly.
8·45	Pottery mine all melted; lumps of ilmenite thrown in.
8·50	2nd fix of pottery mine and scrap thrown on top of first, the object being to cover up the lumps of ilmenite and allow them to become heated gradually, and also to chill the bath of melted ore and set the lumps.
9·45	Scoop of ilmenite lumps thrown into melted bath of ore, the vessel being so arranged that these lumps lie alongside of the first lot thrown in.
9·50	3rd fix of pottery mine and scrap.
11·	Melted bath of ore lodged in next section of vessel, and ilmenite lumps thrown in.

Time. A.M.	
11·5	4th fix of pottery mine and scrap.
11·55	Scoop of ilmenite lumps put in.
12·	5th fix of pottery mine and scrap.
1·	Scoop of ilmenite lumps put in.

NOTE.—This completed the lining and fixing of furnace.

TUESDAY, 7th Nov., 1871.

P.M.	General Observations.	Pig. lbs.	Pd. Bar. lbs.	Tap. Cinder. lbs.
1·20	1st charge. Cleveland pig and cinder -	600	...	...
2·35	Puddled ball drawn Bars -	...	560	...
2·40	2nd charge. Cleveland and cinder -	600	...	...
4·0	Ball ready.			
4·5	Ball drawn - Bars -	...	600	...

During Tuesday night the furnace was fettled with 1,363 lbs. pottery mine, 502 ilmenite lumps, 85 scrap.

WEDNESDAY, 8th Nov., 1871.

A.M.				
6·50	1st charge. Cleveland and cinder -	600	...	...
8·15	Ball drawn - Bars -	...	545	...
8·20	2nd charge. Cleveland and cinder -	600	...	...
9·50	Ball drawn - Bars -	...	631	...
10·0	3rd charge. Cleveland and cinder -	600	...	...
11·30	Ball drawn - - -	...	714	...
11·35	4th charge. Cleveland. Sample for analysis marked $\frac{A}{1}$ - -	600	...	...
P.M. 12·13	Charge nearly melted. Furnace set revolving at 2 to 3 revolutions per minute.			
12·15	Charge all melted. Sample $\frac{A}{2}$.			
12·16	Watered for 2 minutes and occasionally afterwards.			
12·20	Commenced frothing.			
12·21	Fire urged.			
12·23	Machine stopped.			
12·25	Sample $\frac{A}{3}$.			
12·25½	Cinder tapped off - - -	...	...	266

Time. P.M.	General Observations.	Pig. lbs.	Pd. Bar. lbs.	Tap Cinder. lbs.
12·29	Machine revolved at 8 per minute—water run in.			
12·31	Commenced boiling. Water stopped.			
12·35	Sample $\frac{A}{4}$.			
12·40	Iron dropping into grain.			
12·45	Balling up. Sample $\frac{A}{5}$.			
12·50	Ball drawn.			
12·52	Ball squeezed. Sample $\frac{A}{6}$ - -	...	676	...
12·52½	5th charge. Cleveland and squeezer cinder. Sample $\frac{B}{1}$ - -	588	...	...
1.45	All melted. Sample $\frac{B}{2}$.			
1·53	Sample $\frac{B}{3}$.			
1·56½	Cinder tapped out - - -	...	...	214
2·5	Boiling. Sample $\frac{B}{4}$.			
2·13	Balling up.			
2·15	Sample $\frac{B}{5}$.			
2·20	Ball out - - - -	...	672	...
2·25	6th charge. Coneygree and cinder. Sample $\frac{C}{1}$ - - -	620	...	...
3·25	All melted. Sample $\frac{C}{2}$.			
3·30	Sample $\frac{C}{3}$ bar.			
3·30	Cinder tapped off. Sample $\frac{C}{4}$ -	...	...	217
3·53	Ball drawn - - -	...	700	...
3·58	7th charge. Coneygree and cinder. Sample $\frac{D}{1}$ - - -	600	...	...
4·45	All melted. Sample $\frac{D}{2}$.			
4·52	Sample $\frac{D}{3}$.			
4·54	Cinder tapped out - - -	...	...	180
5·18	Ball out - - - -	...	680	...

Furnace fixed during the night.

THURSDAY, Nov. 9th.

A.M.				
9·25	3rd ball for to-day drawn.			
9·30	4th charge. Derbyshire and cinder -	600	...	...
10·3	Melted.			
11·5	Ball drawn - - -	...	673	...

Time. A.M.	General Observations.	Pig. lbs.	Pd. Bar. lbs.	Tap Cinder. lbs.
11·10	5th charge. Derbyshire and cinder. Sample $\frac{E}{1}$.			
11·47	Melted. Sample $\frac{E}{2}$.			
11·55	Sample $\frac{E}{3}$. Cinder tapped - -	...	...	180
11·58	Cylinder revolved at quick speed—iron watered.			
P.M. 12·3	Blast put on.			
12·6	Blast stopped—iron watered.			
12·7	Firing up.			
12·15	Sample $\frac{E}{4}$.			
12·25	Sample $\frac{E}{5}$. Balling up.			
12·30	Ball drawn - - -	...	661	...

NOTE.—The furnace did not work well this heat, in consequence of being too smooth.

Time.	General Observations.	Pig. lbs.	Pd. Bar. lbs.	Tap Cinder. lbs.
12·33	6th charge. Derbyshire and cinder. Sample $\frac{F}{1}$ - - -	600	...	...
1·20	Sample $\frac{F}{2}$. Cinder tapped. Engine out of order. Work stopped $\frac{1}{4}$-hr.			
1·58	Ball ready.			
1·59½	Ball out - - - -	...	677	...
2·1½	7th charge. Derbyshire and cinder. Sample $\frac{G}{1}$.			
2·50	Melted. Sample $\frac{G}{2}$.			
2·55	Sample $\frac{G}{3}$. Cinder tapped - -	...	...	186
2·59	Cylinder revolving at 8 revolutions per minute.			
3·5	Sample $\frac{G}{4}$.			
3·17	„ $\frac{G}{5}$.			
3·18	Balling up.			
3·20	Ball out - - -	...	665	...
3·25	Furnace fettled with Bilbao and Marbella. 8th charge worked before day shift finished.			

THURSDAY NIGHT.

7 charges Derby, and 1 Coneygree, worked.

FRIDAY, 10th November.

Time. P.M.	General Observations.	Pig. lbs.	Pd. Bar. lbs.	Tap Cinder. lbs.
6·20	1st charge. Derby - - -	600	...	...
7·2	Melted.			
7·8	Cinder tapped off - - -	...	...	192
7·38	Balled - - - -	...	665	...
7·42	2nd charge. Derby - -	600	...	...
	Grate cleaned.			
8·37	Cinder tapped off.			
8·50	Ball drawn - - -	...	630	...
8·55	3rd charge. Mostly Welsh crystalline. Cinder 215 lbs. - -	600	...	...
9·35	All melted.			
9·37	Cinder tapped off - - -	...	...	124
9·41	Boiling violently, so that stopper had to be put up.			
9·53	Ready to boil.			
9·55	Tapped 2nd lot of cinder - -	...	...	294
9·57	Balled - - - -	...	601	...
10·	4th charge. Mostly crystal, with only about 20 lbs. cinder - -	600	...	...
10·35	Melted.			
10·39	First portion of cinder tapped off -	...	...	...
	Iron all very fluid—watered.			
10·49	Iron frothing, but not violently.			
10·49	Second portion of cinder tapped off. Total	...	...	233
10·55	Iron commenced dropping.			
11·3	Balled.			
11·6	Squeezed - - -	...	605	...
11·7	Fix or fettling of Bilbao.			
P.M. 12·5	Bilbao melted and Marbella lumps thrown in.			
12·8	5th charge. Crystal. Very little cinder used with this heat. Sample $\frac{H}{1}$ -	600	...	...
12·45	All melted. Sample $\frac{H}{2}$.			
12·48	Cinder tapped - - -	...	...	137
12·49	Iron commenced boiling as soon as tapped.			
12·55	Sample $\frac{H}{3}$.			
12·55	Dropping into grain.			

Time. P.M.	General Observations.	Pig. lbs.	Pd. Bar. lbs.	Tap Cinder. lbs.
1·6	Balled.			
1·9	Drawn.			
1·11	Squeezed - - -	...	605	...
1·12	6th charge. Crystal. Very little slag put in (say 20lbs.) Sample $\frac{I}{1}$ -	600	...	...
	Tapped cinder - - -	...	...	169
2·15	Ball drawn - - -	...	592	...
2·17	7th charge. Crystal. Very little slag used. Sample $\frac{J}{1}$ - - -	600	...	...
3·3	Tapped cinder - - -	...	...	154
3·7½	Sample $\frac{J}{2}$.			
3·13	Cinder boiling over stopper-hole.			
3·16	Sample $\frac{J}{3}$.			
3·22	Ball ready and drawn - -	...	615	...
3·28	Fettling or fix of Bilbao and scrap put in.			
4·15	Fix all melted and Marbella lumps thrown in.			
4·30	8th charge. Derby - -	600	...	...
5·45	Ball drawn - - -	...	620	...

Friday Night.

A.M.				
	Worked all night on Cleveland pig.			
	Bilbao and Marbella used for fettling.			
7·30	Had to fix furnace after first heat.			
	Had to fix furnace again after 3rd heat.			

Saturday, 11th Nov., 1871.

7·45	First ball (Cleveland pig) drawn -	600	695	...
	Tap cinder - - -	...	...	253
7·48	2nd charge. Cleveland - - -	600	...	...
8·45	Cinder tapped - - -	...	...	294
9·5	Ball drawn - - -	...	695	...
9·10	3rd charge. Crystal, with about 20 lbs. squeezed cinder - -	600	...	...
9·45	Tap cinder - - -	...	...	165
10·10	Ball out. 55 lbs metal was tapped with cinder. This is added to weight of bars - - -	...	640	...

Time. A.M.	General Observations.	Pig. lbs.	Pd. Bar. lbs.	Tap Cinder. lbs.
10·15	Fix of Bilbao put in.			
11·10	Lumps of Marbella thrown in.			
	4th charge. Crystal and bar mixed -	600	...	...
	Tap cinder - - -	...	...	202
	Ball out.			
P.M. 12·48	5th charge. Crystal. No cinder. Sample $\frac{M}{1}$	600	...	...
1·22	Cinder tapped - - -	...	...	154
1·24	Sample $\frac{M}{2}$.			
1·35	Balled. Sample $\frac{M}{3}$.			
1·38	Ball out. This bloom is sent home (M).			
1·39	6th charge. Bar pig - -	600	...	...
2·30	Ball out - - -	595	...	155
2·35	7th charge. Bar pig. No slag. Sample $\frac{N}{1}$	600	...	...
3·25	All melted. Sample $\frac{N}{2}$.			
3·26	Tapped cinder - - -	...	...	173
3·34	Sample $\frac{N}{3}$.			
3·44	Balled. Sample $\frac{N}{4}$.			
3·46	Ball out. Squeezer bloom N sent home.			

MONDAY, Nov. 13th, 1871.

Time. A.M.	General Observations.	Pig. lbs.	Pd. Bar. lbs.	Tap Cinder. lbs.
	Fettled with remaining Bilbao and Iron Mountain ore for lumps - -	600	...	...
	1st charge. Bar pig. No cinder put in	...	627	...
7·40	2nd charge. Bar pig. No cinder put in. Sample $\frac{P}{1}$ - - -	600	...	...
	Grate cleaned.			
8·26	All melted. Sample $\frac{P}{2}$.			
8·26½	Cinder tapped - - -	...	...	112
8·40	Dropping into grain. Sample $\frac{P}{3}$.			
8·45	Balled. Sample $\frac{P}{4}$. - -	...	620	...
	NOTE.—No water was used in this charge.			
8·50	3rd charge. Bar Pig. Sample $\frac{R}{1}$.			
9·32	Cinder tapped. Sample $\frac{R}{2}$ - -	...	...	185
9·38	Firing up.			
9·46	Sample $\frac{R}{3}$.			
9·47	Balled. Weight of bloom, 655 lbs.			

NOTE.—This was broken under the hammer when cold, and showed an open spongy texture, but no signs of raw fettling, although examined with greatest care.

		Pig. lbs.	Pd. Bar. lbs.	Tap Cinder. lbs.
4th charge.	Bar pig - -	600	590	175
5th charge.	Bar pig - -	600	615	125
6th charge.	Bar pig - -	600	615	90

NOTE.—As far as we were able to judge, the white iron had no greater action upon the lining than grey, but the opportunity for experimenting upon this point was scarcely extended enough.

DIARY OF No. 5 FURNACE.

NOVEMBER 7TH, 1871.

Cleveland pig iron charged.

Heat.		lbs.	Time. A.M.	Yield. lbs.
1	Weight of charge - - -	600	...	...
	Time of charge - - -	...	10·15	...
	All melted - - -	...	11· 3	...
	Slow speed put on, and water in, machine stopped, and cinder tapped off -	...	11·13	...
	Damper up, fire quick speed on, and blast	...	11·20	...
	On the boil - - -	...	11·23	...
	Dropping - - -	...	11·25	...
	All dropped, and preparing for balling -	...	11·27	...
	Ball formed, and worked up the end of ball with rabble - -	...	11·30	...
	Ready, and out - - -	...	11·33	...
	Weight of puddled bar - -	...	...	681

Total time taken in working the heat, 1 hour, 18 minutes.

Time taken in preparing for next charge, 1 minute, 30 seconds.

Cleveland pig iron charged.

2	Weight of charge - - -	600	...	...
	Time of charge - - -	...	11·35	...
	All melted - - -	...	12·26	...

Heat.		lbs.	Time. A.M.	Yield. lbs.
	Slow speed put on, and water in, machine stopped, and tapped off cinder -	...	12·34	...
	Fire put on, and quick speed with blast -	...	12·37	...
	On the boil - - -	...	12·40	...
	Dropping - - -	...	12·42	...
	All dropped - - -	...	12·43	...
	Machine stopped, to prepare for balling -	...	12·45	...
	Ball made, worked up the front end of ball with rabble.			
	Ready, and out - - -	...	12·48	...
	Weight of puddled bar - -	...	...	728

Total time taken in working the heat, 1 hour, 13 minutes.
Time taken to prepare for next charge, 1 minute.

Cleveland pig iron charged.

3	Weight of charge - - -	600	...	...
	Time of charge - - -	...	12·55	...
	All melted - - - -	...	P.M. 1·40	...
	Slow speed on, and water in, machine stopped, and cinder tapped off -	...	1·56	...
	Balled up and ready - - -	...	2·5	...
	Weight of puddled bar - -	...	...	655

Total time taken in working, 1 hour and 10 minutes.

Cleveland pig iron charged.

4	Weight of pig iron charged - -	600	...	...
	Time of charge - - -	...	2·55	...
	All melted - - - -	...	3·40	...
	Slow speed, and water in, machine stopped, and cinder tapped off - -	...	3·55	...
	Quick speed, fire on and blast.			
	On the boil - - -	...	4·0	...
	Dropped - - - -	...	4·2	...
	Preparing for balling.			
	Balled and ready - - -	...	4·5	...
	Weight of puddled bar - -	...	...	705

This furnace had seven heats this turn, three of the company's ordinary mixture, and four of Cleveland pig iron. All worked upon their own fettling—the Iron Mountain ore.

NOVEMBER 8th.

Cleveland iron charged.

Iron Mountain ores used for fettling.

Heat.		lbs.	Time. A.M.	Yield. lbs.
1	Fettling done on the night previous.			
	Weight of pig iron charged - -	600	...	...
	Time of charge - - -	...	6·10	...
	Heat ready and out - - -	...	7·40	...
	Weight of puddled bar - -	...	...	678
2	Weight of charge - - -	600	...	...
	Time of charge - - -	...	7·42	...
	Ready and out - - -	...	8·57	...
	Weight of puddled bar - -	...	...	630
3	Weight of charge - - -	597	...	...
	Time of charge - - -	...	8·59	...
	Ready and out - - -	...	10·10	...
	Weight of puddled bar - -	...	...	680
4	Weight of charge - - -	600	...	...
	Time of charge - - -	...	10·30	...
	Ready and out - - -	...	11·43	...
	Weight of puddled bar - -	...	...	677

The bars were cleaned before charging this heat.

Conygree iron charged.

5	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	676
6	Cleveland iron charged.			
	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	635
7	Coneygree iron charged.			
	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	666

7 heats to-day. Done work at 3·20 p.m.

Total time taken in working the 7 heats, 9 hours and 10 minutes.

November 9th, 1871.

Derbyshire iron all day.

Worked off Iron Mountain ore fettling.

Heat.		lbs.	Time. A.M.	Yield lbs.
1	First heat charged at - -	...	6·0	...
	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	657
	Bars cleaned this heat.			
2	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	675
3	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	672
4	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	676
5	Weight of charge - - -	602	...	...
	Weight of puddled bar - -	...	...	665
6	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	660
7	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	660
8	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	660

Finished the 8 heats at 3 o'clock p.m.

Time taken in working the 8 heats, 9 hours.

No fettling between heats during the day.

Put in fettling at 3 o'clock p.m. Melted at 3·35 p.m.

November 10th, 1871.

Cleveland iron worked.

They worked 8 heats this turn.

The weight of puddled bar per heat was as in first column.

Heat.		lbs.	Yield lbs.
1	- - - - -	600	530
2	- - - - -	600	570
3	- - - - -	600	683
4	- - - - -	600	605
5	- - - - -	600	605

Heat.		lbs.	Yield lbs.
6	- - - - -	600	575
7	- - - - -	600	695
8	- - - - -	600	665

These heats were worked off Iron Mountain ores as fettling. The fettling of this furnace was done during the previous night.

Partial Diary of No. 5 Furnace—Nov. 10th.

Time. A.M.	General Observations.	Pig.	Pd. Bar.	Tap Cinder.
6·0	1st charge. Cleveland - -	600	...	...
7·10	Ball out. The first in the mill from day shift.			
8·30	2nd ball out.			
	Saturday, November 11th.			
8·40	4th charge. Crystal pig.			
9·45	5th charge. Crystal pig—very little cinder used - - -	600	...	40
10·55	Ball out - - -	...	605	...
	Note.—The bars from this charge were specially marked, and rolled into a rail separately.			
10·58	6th charge. Crystal - -	...	...	297
11·54	Ball out.			
11·56	7th charge. Crystal - -	600	...	137
12·	Ball out.			

Note.—The cast iron ring at the flue end of the machine cracked at this point, and the work was stopped for the day. The necessary repairs were made on Saturday, and the furnace got ready to start first thing on Monday.

Monday, November 13th.

	1st charge. Bar pig - -	600	580	...
	2nd charge. Bar pig and 20 lbs. cinder or slag - - -	600	615	...
8·18	Fixing furnace, as this was not done at starting.			
8·45	Lumps put in.			

		lbs.		Yield lbs.
3rd charge.	Bar pig - - -	600	...	565
4th charge.	Bar pig - - -	600	...	600
5th charge.	Bar pig - - -	600	...	590
6th charge.	Bar pig - - -	600	...	625

NOTE.—These charges of white iron were made in No. 5 furnace in order to try whether the yield would be better if worked on Iron Mountain ore as fettling, but no practical difference is to be observed. The smaller yield from white iron than from grey is evidently to be attributed to the nature of the iron. This point will be treated of in the special report.—(G. J. S.)

DIARY OF No. 6 FURNACE.

For week ending Nov. 11th, 1871.

NOVEMBER 7th, 1871.

Cleveland iron charged.

Heat.		Charge. lbs.	Time. A.M.	Yield. lbs.
1	Time of charge - - -	600	6·30	...
	Turned iron over - - -	...	6·40	...
	Turned iron over again - -	...	6·50	...
	Melting - - - -	...	7·0	...
	All melted - - - -	...	7·10	...
	Slow speed and water in, with blast off.			
	Ceased putting in water - -	...	7·20	...
	Tapped off cinder - - -	...	7·25	..
	Fire and blast put on, with quick speed.			
	On the boil - - -	...	7·35	...
	Dropping - - - -	...	7·45	...
	All dropped - - -	...	7·50	...
	Preparing the iron for balling.			
	Turned the machine twice, and ball made.			
	Worked up the front end of ball with rabble, and put fire on.			
	Turned machine slowly again once to soak ball.			

Heat.		Charge. lbs.	Time. A.M.	Yield. lbs.
	Ready and out, with heat - -	...	7·52	...
	Weight of puddled bar - -	...	...	540

Total time of working the heat, 1 hour and 22 minutes.

Time taken in preparing for next charge, 1 minute 30 seconds.

Cleveland iron charged.

2	Weight of iron charged - -	600	...	...
	Time of charge - - -	...	8·0	...
	All melted. Slow speed - -	...	8·35	...
	Put in water, and blast off.			
	Tapped off cinder - - -	...	8·48	...
	Stopped tap - - -	...	8·55	...
	Quick speed on, fire with damper up a little.			
	Blast on, and damper up.			
	On the boil - - -	...	9·0	...
	Commenced dropping - -	...	9·4	...
	All dropped - - -	...	9·7	...
	Machine stopped.			
	Preparing iron for balling.			
	Turned machine over twice slowly to form the ball.			
	Ball made - - -	...	9·10	...
	Worked up the end of the ball.			
	Ready, and out with heat - -	...	9·12	...
	Weight of puddled bar - -	...	...	615

Total time taken in working the heat, 1 hour 12 minutes.

Time taken in preparing for next charge, 1 minute 48 seconds.

Cleveland iron charged.

3	Weight of pig iron charged - -	609	...	...
	Time of charge - - -	...	9·20	...
	All melted - - -	...	10·5	...
	Blast off, and water put in.			
	Tapped off cinder - - -	...	10·15	...
	Damper up, blast on, with quick speed -	...	10·23	...
	On the boil - - -	...	10·30	...
	Dropping - - - -	...	10·35	...
	All dropped - - -	...	10·37	...

Heat.		Lbs.	Time. A.M.	Yield lbs.
	Stopped the machine to prepare for balling.			
	Turned the machine twice to form the ball.			
	Worked up the end of the ball with rabble.			
	Ball formed - - -	...	10·39	...
	Ready and out with heat - -	...	10·41	...
	Weight of puddled bar - -	...	...	607
	Total time taken in working the heat, 1 hour and 21 minutes.			
	New fettling this heat put in - -	...	10·50	...
	All melted and put in lumps - -	...	11·30	...
	Time taken in fettling furnace, 40 minutes.			
	Cleveland iron charged.			
4	Weight of pig iron charged - -	600	...	...
	Time of charge - - -	...	11·44	...
	All melted - - -	...	P.M. 12·32	...
	Blast off and water in, with slow speed.			
	Tapped off cinder - - -	...	12·40	...
	Quick speed. Damper up. Fire on and blast - - -	...	12·44	...
	On boil - - - -	...	12·45	...
	Dropping - - - -	...	12·55	...
	All dropped - - -	...	12·58	...
	Machine stopped to prepare for balling.			
	Ball made - - -	...	1·0	...
	Worked up the end of ball with rabble.			
	Ready, and out with heat - -	...	1·2	...
	Weight of puddled bar - -	...	...	614
	Total time taken in working the heat, 1 hour 18 minutes.			
	Time taken in preparing for next charge, 1 minute 30 seconds.			
	Cleveland pig iron charged.			
5	Weight of pig iron charged - -	600	...	...
	Time of charge - - -	...	1·8	...
	All melted - - -	...	1·49	...
	Slow speed, and water put in.			
	Cinder tapped off - - -	...	2·9	...
	Damper up. Fire on and blast, with quick speed.			

Heat.		lbs.	Time. P.M.	Yield. lbs.
	On the boil - - -	...	2·15	...
	Dropping - - -	...	2·25	...
	All dropped - - -	...	2·27	...
	Machine stopped to prepare for balling.			
	Ball made - - -	...	2·28	...
	Ready, and out with heat - -	...	2·30	...
	Weight of puddled bar - -	...	...	591

Total time taken in working the heat, 1 hour 22 minutes.

Time taken in preparing for next charge, 1 minute 30 seconds.

Cleveland pig iron charged.

6	Weight of pig iron charged - -	601	...	...
	Time of charge - - -	...	2·50	...
	All melted - - -	...	3·30	...
	Slow speed, and water in.			
	Machine stopped, and cinder tapped off -	...	3·50	...
	Fire put on, with quick speed and blast. Damper up a little.			
	On the boil - - -	...	4·0	...
	All dropped - - -	...	4·5	...
	Machine stopped to prepare for balling.			
	Ball made. Worked up the end with rabble, and ready - -	...	4·8	...
	Weight of puddled bar - -	...	...	611

Total time taken in working the heat, 1 hour 18 minutes.

Six heats to-day, because of furnace working very badly indeed, in conseqence of flue being out of repair.

Total time taken in working six heats and once fettling to-day, 9 hours 38 minutes.

NOVEMBER 8TH, 1871.

Cleveland iron charged.

Cleaned bars before charging first heat.

1	Weight of charge - - -	600	...	...
	Time of charge - - -	...	6·20	...
	Ready, and on - - -	...	7·45	...
	Weight of puddled bar - -	...	...	648

Total time taken in working the heat, 1 hour 25 minutes.

Heat.		Lbs.	Time. A.M.	Yield. lbs.
2	Weight of charge - - -	600	...	...
	Time of charge - - -	...	7·47	...
	Ready, and on - - -	...	8·55	...
	Weight of puddled bar - -	...	...	652

Total time taken in working the heat, 1 hour 8 minutes.

Cleaned bars again this heat.

After this heat Pittsburgh coal was used, which is considered very suitable. Hocking Valley coal was used before, which is considered very inferior, and only used when other coals cannot be obtained.

Coneygree pig iron charged.

3	Weight of charge - - -	600	...	...
	Time of charge - - -	...	9·10	...
	All melted - - -	...	10·3	...
	Slow speed on, and water put in.			
	Machine stopped to tap off cinder -	...	10·13	...
	Quick speed on, fire, damper up, and blast put on - - -	...	10·16	...
	On the boil - - -	...	10·20	...
	Dropping - - - -	...	10·25	...
	All dropped - - -	...	10·28	...
	Preparing for balling.			
	Ball made - - -	...	10·31	...
	Worked up the end of ball with rabble.			
	Ready, and on - - -	...	10·33	...
	Weight of puddled bar - -	...	...	637

Total time taken in working the heat, 1 hour 23 minutes.

Coneygree pig iron charged.

4	Weight of charge - - -	606	...	...
	Time of charge - - -	...	10·41	...
	All melted - - -	...	11·25	...
	Slow speed and water put in.			
	Tapped off cinder - - -	...	11·35	...
	Quick speed, fire on, damper up, and blast on - - -	...	11·40	...
	On the boil - - -	...	11·42	...
	Dropping - - -	...	11·44	...

Heat.		lbs.	Time. A.M.	Yield. lbs.
	All dropped	...	11·46	...
	Preparing for balling.			
	Ball made	...	11·48	...
	Worked up the end of ball with rabble.			
	Ready, and on	...	11·50	...
	Weight of puddled bar	...	...	660

Time taken in working the heat, 1 hour and 9 minutes.

This heat was tapped very dry, which brought it on very quick.

Derbyshire pig iron charged.

			P.M.	
5	Weight of charge	600	...	...
	Time of charge	...	12·0	...
	All melted	...	12·31	...
	Slow speed put on, and water put in.			
	Machine stopped, and cinder tapped off	...	12·45	...
	Quick speed put on, damper up, and blast put on, with fire.			
	On the boil	...	12·50	...
	Dropping	...	12·53	...
	All dropped	...	12·55	...
	Preparing for balling.			
	Ball made	...	12·58	...
	Worked up the end of the ball with rabble.			
	Ready	...	1·0	...
	Weight of puddled bar	...	...	656

Time taken in working the heat, 1 hour.

Cleaned bars again this heat.

Cleveland iron charged.

6	Weight of pig iron charged	600	...	...
	Weight of puddled bar	...	...	665

Coneygree iron charged.

7	Weight of pig iron charged	600	...	...
	Weight of puddled bar	...	...	676

Seven heats to-day; no fettling; done work 3·45 p.m. Time taken in working the seven heats, 9 hours and 25 minutes.

NOVEMBER 9th, 1871.

All Derbyshire iron to-day.

The furnace was fettled on the previous night for to-day.

Heat.		lbs.	Time. A.M.	Yield. lbs.
1	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	640
2	Cleaned bars this heat.			
	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	680
3	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	668
4	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	664
5	Weight of charge - - -	600	...	...
	Time of charge - - -	...	11·7	...
	All melted - - - -	...	11·47	...
	Slow speed, and water put in.			
	Stopped machine to tap off cinder -	...	11·55	...
	Quick speed on, fire, damper up, and blast on	...	11·57	...
	On the boil - - -	...	12·0	...
			P.M.	
	Dropping - - - -	...	12·3	...
	All dropped - - -	...	12·5	...
	Machine stopped to prepare for balling.			
	Ball made - - - -	...	12·7	...
	Work up the end of ball with rabble.			
	Ready and out - - -	...	12·11	...
	Cleaned bars again this heat.			
	Time taken in working the heat, 1 hour and 4 minutes.			
6	Weight of charge - - -	600	...	...
	Time of charge - - -	...	12·25	...
	All melted - - - -	...	1·4	...
	Slow speed, and water put in.			
	Stopped the machine, and tapped off cinder	...	1·10	...
	Quick speed put on, damper up, fire put on, and blast - - -	...	1·14	...
	On the boil - - -	...	1·16	...
	Dropping - - - -	...	1·19	...

Heat.		lbs.	Time. P.M.	Yield. lbs.
	All dropped - - -	...	1·21	...
	Stopped the machine, and prepared for balling.			
	Ball made - - - -	...	1·23	...
	Ready - - - -	...	1·24	...
	Time taken in working the heat, 59 minutes.			
	Weight of puddled bar - -	...	...	685
7	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	633
	Time of charge - - -	...	1·30	...
	Out with heat - - -	...	2·35	...
8	Weight of charge - - -	600	...	...
	Weight of puddled bar - -	...	...	685

Finished the eight heats at	3·50 P.M.
Put in fettling	3·50 „
Melted	4·24 „
Put in No. 2 fettling, or second	4·35 „
Melted	5·30 „

No. 6 furnace began to-night to work double turns.
Cleaned bars, and charged 1st heat at 6 o'clock P.M.

NOVEMBER 9TH, Night Turn, Thursday Night.

Coneygree pig iron used.

All blooms made on the night turn could not be rolled for want of steam, but were heated and rolled on the following day.

The weight of the charges were as follows :—

Heat.	Charge. lbs.		Yield. lbs.
1 - - - - -	602	...	665
2 - - - - -	600	...	660
3 - - - - -	606	...	660
4 - - - - -	600	...	523
5 - - - - -	600	...	635
6 - - - - -	600	...	668
7 - - - - -	604	...	Blooms.
8 - - - - -	600	...	„

The weight of puddled bar per heat, after rolling on the day following, were as per column opposite the weight of charges.

	Blooms. lbs.
Two of the blooms, which were not re-heated or rolled, weighed as per column - -	728 and 700

NOVEMBER 10TH, 1871, Day Turn.

Coneygree pig iron used this turn.

	lbs.
No. 6 furnace had eight heats this turn. All charges weighed - - -	600

The weights per heat of puddled bar were as follow :—

Heats.	Yield.
1 - - - - -	690
2 - - - - -	680
3 - - - - -	684
4 - - - - -	670
5 - - - - -	650
6 - - - - -	683
7 - - - - -	655
8 - - - - -	655

They cleaned their bars before charging the first heat, and again when the fifth heat was out.

The furnace was fettled when the sixth heat was out.

NOVEMBER 10TH, 1871, Night Turn.

Five heats of Coneygree iron charged, and three of tin plate, Welsh.

Heats.		lbs.	Yield.
1	Weight of charge per heat - -	600 ...	683
2	- - - - -	600 ...	680
3	- - - - -	600 ...	664
4	- - - - -	600 ...	653
5	- - - - -	600 ...	695

The following three heats were tin plate, Welsh :—

		Lbs.	Yield. lbs.
6	Weight of charge per heat - -	600 ...	690
7	- - - - -	600 ...	620
8	- - - - -	600 ...	620

This turn they had three heats, and put in one fettling.

The furnace was also fettled before the first heat was charged. Fettling was again put in when the last heat was out.

The ore used for fettling was all Lisbon, both small and lumps.

PARTIAL DIARY OF No. 6 FURNACE—FRIDAY, November 10th.

Time. A. M.	General Observations.	Pig.	Pd. Bar.	Tap Cinder.
6·15	1st charge. Coneygree - -	600	...	...
6·45	All melted.			
7·12	Cinder tapped.			
7·20	Dropping into grain.			
7·36	Ball out.			
8·38	2nd ball Coneygree out.			

SATURDAY, December 11th.

Lisbon ore used entirely for fettling. This did not stand well, and required frequent renewal.

7·40	1st charge. Tin plate pig - -	600	...	...
8·35	Cinder tapped off.			
8·50	Ball out.			
8·55	2nd charge. Tin plate, pig, and cinder. Sample $\frac{K}{1}$ - - -	600	...	...
9·30	All melted. Sample $\frac{K}{2}$. Watered. Machine going $3\frac{1}{2}$ revol. per minute.			
9·39	Sample $\frac{K}{3}$. Cinder tapped off - Quick speed put on, fired, and blast put on.	...	...	370
9·50	Sample $\frac{K}{4}$. Iron boiling up to stopper-hole.			
10·0	Ball out. Sample $\frac{K}{5}$. NOTE.—This bloom is sent home (K)			
10·0	3rd charge. Tin plate, pig, and cinder -	600	...	...
10·55	Cinder tapped off - - -	...	...	303
11·15	Ball out - - -	...	660	...
11·20	4th charge. Tin plate, pig, and cinder. Sample $\frac{L}{1}$ - - -	600	...	...
P.M. 12·5	All melted. Sample $\frac{L}{2}$.			
12·13	Sample $\frac{L}{3}$. Tapped cinder - -	...	...	385
12·23	Sample $\frac{L}{4}$. Dropping into grain.			
12·30	Ball drawn. - - -	...	655	...
12·34	Charge tin plate, pig, and cinder.			

NOTE.—The brickwork of movable flue gave way just as the iron had got to red heat, and the charge had therefore to be withdrawn during the repairs.

Time. P.M.	General Observations.	Pig.	Pd. Bar.	Tap Cinder.
2·45	5th charge. Tin plate, pig, and cinder.			
	Sample $\underset{1}{\text{O}}$ - - -	600	...	...
3·30	All melted. Sample $\underset{2}{\text{O}}$.			
3·38	Cinder tapped off - - -	...	...	446
3·41	Sample $\underset{3}{\text{O}}$.			
3·51	Sample $\underset{4}{\text{O}}$.			
3·56	Balled $\underset{5}{\text{O}}$. - - -	...	620	...

NOTE.—The bars from this heat were piled separately, and the rail crops therefrom are sent home.

*** *In all cases, throughout this report, the "weight of bars" means actual weight of puddled bars obtained from the reheated and rolled puddled blooms.*

APPENDIX TO JOURNAL.

THE IRON AND STEEL INSTITUTE.

RULES.

1.—The Society shall be designated "THE IRON AND STEEL INSTITUTE."

2.—The objects of the Institute shall be—

To afford a means of communication between members of the Iron and Steel Trades upon matters bearing upon the respective manufactures, excluding all questions connected with wages and trade regulations.

To arrange periodical meetings for the purpose of discussing practical and scientific subjects bearing upon the manufacture and working of iron and steel.

SECTION I.—CONSTITUTION.

3.—The Institute shall consist of members who shall be more than twenty-one years of age, and shall have one or other of the following qualifications:—

(*a*) Persons practically engaged in works where iron or steel is produced or worked.

(*b*) Persons of scientific attainments in metallurgy, or specially connected with the application of iron or steel.

SECTION II.—ELECTION OF MEMBERS.

4.—A recommendation for admission according to Form A in the Appendix shall be forwarded to the Secretary, and by him be laid before the Council. The recommendation to be in writing, and to be signed by not less than three members.

5.—Such applications for admission as are approved by a majority of the Council, shall be inserted on a voting list. This voting list shall specify the name, occupation, address, and proposers of the candidates, and shall be forwarded to the members at least fourteen days previous to the next general meeting, when the lists that have been returned to the Secretary shall be opened, only in presence of the members, by Scrutineers, to be appointed by the meeting for that purpose. The elections shall take place at the general meetings only.

6.—The election shall take place by ballot, three-fifths of the votes recorded being necessary for election.

7.—When the proposed candidate is elected, the Secretary shall give him notice thereof, according to Form B, but his name shall not be added to the list of Members of the Institute until he shall have paid his first annual subscription, and signed the Form C in the Appendix.

8.—In the case of non-election, no mention shall be made thereof in the minutes, nor any notice given to the unsuccessful candidate.

SECTION III.—OFFICERS AND MODE OF ELECTION.

9.—The Officers of the Institute, for the management of its affairs, shall consist of one President, nine Vice-Presidents, fifteen Members of Council, one Secretary, and one Treasurer. All members who have filled the office of President of the Institute shall be *ex-officio* permanent Members of Council, under the title of Past Presidents.

10.—The President shall be elected for two years, and shall not be eligible for re-election until after an interval; three Vice-Presidents, and five Members of the Council, in rotation, shall retire annually, but shall be eligible for re-election.

11.—Candidates shall be put in nomination at the ordinary general meeting preceding the annual meeting, when the Council shall present a list specifying which of the number offer themselves for re-election. Any member shall be then entitled to add names to the list of candidates. Members may also nominate canditates for office up to one month previous to the annual meeting, the names to be sent to the Secretary. The voting list of the proposed names shall be forwarded to the members, and must be returned to the Secretary previous to the election.

12.—Each member may erase any name or names from the list, but the number of names on the list, after such erasure, must not exceed the number to be elected to the respective offices as before enumerated. The lists which do not accord with these directions shall be rejected by the Scrutineers. The votes for any member who may not be elected as President, or Vice-President, shall count for him as Vice-President or other Member of the Council. The voting to be conducted in the manner specified in Section II.

13.—The Council shall have power to fill up any vacancies that may occur during their year of office.

SECTION IV.—DUTIES OF OFFICERS.

14.—The President shall be chairman at all meetings at which he shall be present, and in his absence one of the Vice-Presidents. In the

absence of a Vice-President, the members shall elect a chairman for that meeting.

15.—The Treasurer shall hold in trust the uninvested funds of the Institute, which shall be deposited, in the name of the Society, at a bank approved by the Council; he shall receive all monies, and shall pay all accounts that are properly certified as correct by the Council; and shall present, from time to time, a statement of the Society's accounts.

16.—The Secretary shall attend all meetings, shall take minutes of the proceedings, shall be responsible for the safe custody of all papers, books, and other property of the Institution, and, under the direction of the Council, shall conduct the general business of the Institute.

SECTION V.—MEETINGS.

17.—There shall at least be two general meetings in each year, one of which shall be held in London, in the spring, and the other in August or September in such locality as the Council may direct. The meeting in spring shall be the annual meeting for the election of officers.

18.—Twenty members shall be entitled to call, through the Secretary, a special meeting, the objects thereof to be stated in the requisition. The business of such meetings shall be confined to the special subjects named in the notice convening the same.

19.—All members shall have notice of, and shall be entitled to attend each meeting of the Institute, and to receive copies of the Society's Transactions gratuitously.

20.—No alteration of the Rules or Bye-Laws shall be made except at the annual meeting, and a notice of any proposed alteration shall be given at the general meeting, to be held in August or September.

SECTION VI.—SUBSCRIPTIONS.

21.—The subscription of each member shall be two guineas per annum; and members elected after January 1st, 1870, shall pay an entrance fee of two guineas each.

22.—The subscriptions shall be payable in advance, on January 1st in each year. Any member whose subscription shall be twelve months in arrear, shall forfeit all the privileges of the Institution; and the Council, after having given due notice, in the Form D in the Appendix, shall be empowered to remove such names from the lists of the Institution.

SECTION VII.—COMMUNICATIONS OF MEMBERS.

23.—All communications shall be submitted to the Council, and, after their approval, shall be read at the general meetings.

24.—All communications made to the Institute shall be the property of the Society, and shall be published only in the Transactions of the Institute, or by the authority of the Council.

SECTION VIII.—PROPERTY OF THE INSTITUTION.

25.—All the property of the Institute, other than funds in the hands of the Treasurer, shall be held by three Trustees, in trust, for the Society. The Trustees shall be appointed by the members in general meeting assembled; and in case any vacancy in the Trustees occurs, the same shall be filled by election at the next general meeting—the Chairman, in all cases, having a second or casting vote.

26.—All books, drawings, communications, models, and the like, shall be accessible to all members and associates, according to the Bye-Laws. The Council shall have power to deposit the same in such place or places as may be considered most convenient for the members.

27.—Every person desirous of bequeathing to the Institute any personal property, is requested to make use of the following form in his will:—I give and bequeath to the Trustees of the Iron and Steel Institute in London [here mention the property or sum of money intended to be bequeathed], for the use of the Institute.

SECTION IX.—CONSULTING OFFICERS.

28.—The members in general meeting assembled shall have power to appoint such consulting officers as may be thought desirable, from time to time, and may vote them suitable remuneration.

SECTION X.—PRIZES.

29.—The Society may offer annually a certain sum to be appropriated in Prizes or Medals, for Essays on subjects prescribed by the Council, for inventions of a specified character, or for improvements in special departments of the iron or steel manufactures. A list of the subjects for which prizes will be given shall be presented in each annual report.

SECTION XI.—DISSOLUTION.

30.—The Institute shall not be broken up unless upon the vote of two-thirds of the members present at any general meeting, convened for the purpose of considering the dissolution; and after confirmation by a similar vote, at a subsequent meeting, to be held not less than three, or more than six months after the first; and notice of this last meeting shall be duly advertised as the Council or a general meeting may advise.

APPENDIX.

FORM A.

Mr. A. B. (address in full), being of the required age, and desirous of becoming a member of the Iron and Steel Institute, we, the under-

signed, from our personal knowledge, do hereby recommend him for election.

His qualifications are____

____

Witness our hands this________day of________, 18

____ Names of
____ Three
____ Members.

FORM B.

Sir,—I beg to inform you that on the___________you were elected a member of the Iron and Steel Institute, but, in conformity with the Rules, your election cannot be confirmed until the accompanying form be returned to me with your signature, and until your first annual subscription, the amount of which is________, be paid to the Treasurer, Mr.______________. If the first subscription is not received within two months of this date, your election will become void.

I am, Sir, your obedient Servant,

________________________________Secretary.

______day of______, 18

FORM C.

I, the undersigned, being elected a member of the Iron and Steel Institute, do hereby agree that I will be governed by the regulations of the said Institution, as they are now formed, or as they may be hereafter altered, that I will advance the interests of the Institution as far as may be in my power, provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand this_______day of_______18

FORM D.

Sir,—I am directed to inform you that your subscription to the Iron and Steel Institute, amounting to__________, is in arrear, and that, if the same be not paid to the Treasurer, Mr.__________, on or before the __________day of__________, 18_____, your name will be removed from the lists of the Institute.

I am, Sir, your obedient Servant,

________________________________Secretary.

THE IRON AND STEEL INSTITUTE,

ESTABLISHED 1869.

OFFICERS FOR 1872-73.

President.

HENRY BESSEMER.

Past President.

THE DUKE OF DEVONSHIRE, K.G.

Trustees.

BOLCKOW, H. W. F., M.P.	Middlesbrough.
HARTLEY, JOHN	Wolverhampton.
RICHARDS, E. M., M.P.	Swansea.

Vice-Presidents.

ALLEYNE, SIR JOHN G. N., Bart. ...	Butterley.
BELL, I. LOWTHIAN, F.C.S.	Newcastle-on-Tyne.
CASSELLS, ROBERT	Glasgow.
FOWLER, WILLIAM	Sheepbridge.
HEATH, ROBERT	Stoke-on-Trent.
KITSON, F. W.	Leeds.
MENELAUS, WILLIAM	Dowlais.
SMITH, JOSIAH T.	Barrow-in-Furness.
WILLIAMS, WALTER	Tipton.

Council.

ADDENBROOKE, GEORGE	Wednesbury.
BAGNALL, CHARLES	Whitby.
BARKER, G. J.	Wolverhampton.
BROGDEN, A., M.P.	Ulverston.
CRAWSHAY, W. T.	Merthyr Tydvil.
DAWES, GEO.	Barnsley.
FOTHERGILL, R., M.P.	Aberdare.
HORTON, THOMAS E.	Lilleshall.
HOPKINS, W. R. I.	Middlesbrough.
LANCASTER, J., M.P.	Wigan.
RODEN, W. S., M.P.	Stoke-on-Trent.
SIEMENS, C. W.	London.
WHITWORTH, SIR J.	Manchester.
WILLIAMS, EDWARD	Middlesbrough.
WILSON, GEORGE	Sheffield.

Treasurer.

DALE, DAVID ... ... Darlington.

Bankers.

THE NATIONAL PROVINCIAL BANK OF ENGLAND.

General Secretary.

JONES, JNO., F.G.S. ... Iron Trade Offices, Middlesbrough.

Foreign Secretary.

FORBES, DAVID, F.R.S. ... 11, York Place, Portman Square, London, W.

LIST OF MEMBERS,

MADE UP TO MARCH 19, 1872,

Abbot, Thomas, Team Valley Iron Works, Gateshead.
Adams, Jno., Hollinswood, near Wellington, Salop.
Adams, George, Priestfields, near Wolverhampton.
Adams, William, Cardiff.
Adamson, Daniel, Engineer, Hyde, Manchester.
Addenbrooke, George, Rough-hay Iron Works. Darlaston,
Addenbrooke, John, Rough-hay Iron Works, Darlaston.
Addie, John, Langloan Iron Works, Glasgow.
Ainslie, W. G., 3, East India Avenue, Leadenhall Street, London, E.C.
Ainslie, Aymer, Ulverstone, Lancashire.
Ainsworth, George, Consett Iron Works, Blackhill, Co. Durham.
Aitken, Henry, Almond Iron Works, Falkirk, N.B.
Alexander, Edward, Iron Shipbuilder, Hartlepool.
Allen, William Daniel, Bessemer Steel Works, Sheffield.
Alleyne, Sir John G. N., Bart., Butterley Iron Works, Alfreton.
Allport, Howard Aston, Midland Railway Co., Bedford.
Anderson, Charles K., 19, Westbourne Square, London, W.
Anderson, Thomas Henry, Westbury Iron Works, Wilts.
Anstice, W. R., Madeley Wood, Iron Bridge, Salop.
Armitage, William J., Farnley Iron Works, near Leeds.
Armstrong, Isaac, Solway Hematite Iron Co., Maryport.
Armstrong, Sir William G., Elswick Iron Works, Newcastle,
Attwood, Charles, Wolsingham, Co. Durham.
Ayrton, William Scrope, Saltburn-by-the-Sea.

Backhouse, Thomas, Cleveland Iron Shipyard, Middlesbrough.
Bagnall, Charles, Grosmont Iron Works, via York.
Bagshawe, J. J., Thames Steel Works, Sheffield.
Baker, William, 46, High Street, Sheffield.
Baldwin, Alfred, Wilden, near Stourport.
Banks, George H., Pontymister, Newport, Monmouthshire.
Bantock, Thomas, Merridale House, Wolverhampton.

Barclay, J., Bowling Iron Works, Bradford, Yorkshire.
Barker, George J., Chillington Iron Works, Wolverhampton.
Barker, Thomas, Queen Steel Works, Sheffield.
Barrows, Wm., Bloomfield Iron Works, Tipton.
Barrett, Wm., Norton Iron Works, Stockton.
Bartholomew, Charles (C.E.), Broxholme, Doncaster.
Barton, Edward, Carnforth Hematite Iron Works, Carnforth.
Bayo, Federiro, La Felguera Iron Works, Asturias, Spain.
Beaumont, Capt. F.E.B., (M.P.) House of Commons, London.
Bedson, George, Bradford House, Manchester.
Bell, I. Lowthian, Washington Hall, Co. Durham.
Bell, John, Saltburn-by-the-Sea, Yorkshire.
Bell, John T., Monkwearmouth Iron Works, Sunderland.
Bell, Thomas, Walker Iron Works, Newcastle.
Bell, T. Hugh, Clarence Iron Works, Middlesbrough.
Bell, Thomas, jun., Clarence Iron Works, Middlesbrough.
Bennett, Peter Duckworth, Spon Lane Foundry, West Bromwich.
Benson, George Henry, Staleybridge, or Fairfield, Manchester.
Bessemer, Henry, Denmark Hill, London, S.E.
Bewicke, Thomas John, 2, Westminster Chambers, Victoria Street, London, S.W.
Biddulph, John, Swansea.
Binns, Charles, Clay Cross, Chesterfield.
Birch, John, Railway Steel and Plant Co., Manchester.
Bladen, Charles, Blochairn Iron Works, Glasgow.
Blair, Thomas S., Ironmaster, Pittsburgh, Pennsylvania, U.S.A.
Bleckly, Henry, Ironmaster, Warrington.
Bleckly, John James, Warrington.
Bleckly, W. H., Ashfield, Warrington.
Bloomer, Caleb, Hill Top, West Bromwich.
Bodmer, J. J., Engineer, 23, The Grove, Hammersmith, London, W.
Bolckow, H. W. F. (M.P.), Middlesbrough.
Bolckow, C. F. H., Middlesbrough.
Borrie, John, Cleveland Iron Works, Southbank, Middlesbrough.
Bouch, William, Shildon Works, Darlington.
Bourne, John, 66, Mark Lane, London, E.C.
Bourne, Septimus, West Cumberland Iron Works, Workington.
Brady, Sir Antonio, Maryland Point, Sratford, E.
Bragge, William, Atlas Iron Works, Sheffield.
Briggs, Joseph, Iron Foundry, Barrow-in-Furness.
Brogden, Alexander, (M.P.), Ulverston, Lancashire.

Brogden, James, Tondu Iron Works, Bridgend, Glamorganshire.
Brogden, Henry, Hale Lodge, Altrincham, Manchester.
Brown, George, Atlas Works, Sheffield.
Browne, W. R., Cookley Iron Works, Kidderminister.
Buckley, R. O., 19, Cleveland Square, Hyde Park, London, W.
Burdin, James, A., Troy, New York, U.S.A.
Butler, J. O., Kirkstall Forge, Leeds.

Cabry, Charles, North Eastern Railway, York.
Carbutt, E. Hamer, Bradford, Yorkshire.
Carrington, Arthur, Wingerworth Iron Works, Chesterfield.
Carrington, Thomas, Wingerworth Furnaces, Chesterfield.
Cassells, Robert, 166, St. Vincent Street, Glasgow.
Cavendish, Lord Frederick (M.P.), Holker Hall, Grange, Lancashire
Chatelier, L. le, 33, Rue Madame, Paris.
Checkland, George E., Market Street, Leicester.
Claridge, Thomas, Bilston.
Clark, James, Heath Green, Newton Heath, Manchester.
Claye, S. John, Manor House Works, near Derby.
Cliff, Joseph, Western Flatts, Wortley, near Leeds.
Cliff, Joseph, jun., Frodingham Iron Works, Brigg, Lincolnshire.
Cockburn, William, Upleatham, Marske-by-the-Sea, Yorkshire.
Cochrane, Charles, The Grange, near Stourbridge.
Cochrane, Henry, Ormesby Iron Works, Middlesbrough.
Colquhoun, James, Llynvi Iron Works, near Bridgend, Glamorganshire.
Cooke, William, 179, Wood View, Burngreave Road, Sheffield.
Cowper, Charles Edward, 3, Great George Street, Westminster, S.W.
Cowper, E. A. (C.E., M.E.), 6, Great George Street, Westminster, S.W.
Crampton, Thomas R., 12, Great George Street, Westminster, S.W.
Crawshay, George, Gateshead-on-Tyne.
Crawshay, W. T., Cyfarthfa Castle, Merthyr Tydvil.
Crewdson, W. D., jun., Kendal Bank, Kendal.
Criswick, Theophilus, 8, Gore Terrace, Swansea.
Crompton, George, Stanton Iron Works, Nottingham.
Crossley, William, Furness Iron and Steel Co., Askam, Lancashire.
Crowe, Edward, Tees Side Iron Works, Middlesbrough.
Currey, William, 14, Great George Street, Westminster, London, S.W.
Cunninghame, John, 127, St. Vincent Street, Glasgow.

Daglish, Robert, Aston Hall, near Preston Brook, Cheshire.
Dale, David, Shildon Works, Darlington,
Darby, Abraham, Ebbw Vale Iron Works, Ebbw Vale, Newport, Mon.

Davey, George H., Baglan, near Heath, Glamorganshire.
Davis, William, Gadlys Iron Works, Aberdare,
Dawes, George, Elsecar Iron Works, Barnsley.
Dawes, W. H., Bromford Iron Works, West Bromwich.
Deas, James, Whitehaven.
Devonshire, the Duke of, Holker Hall, Grange, Lancashire.
Dillwyn, Lewis Llewellyn, Hendrefoilan, Swansea.
Dixon, Raylton, Cleveland Iron Shipyard, Middlesbrough.
Dobbs, Charles James, Cargo Fleet Works, Middlesbrough.
Dodds, Joseph, (M.P.), North Yorkshire Iron Company, Stockton.
Douglas, C. P., Consett House, Blackhill, Durham.
Douglas, Thomas, Millwall Iron Works, London, E.
Downey, Alfred C., Coatham Iron Works, Middlesbrough.
Drane, Thomas, West Cumberland Iron Works, Workington.
Dudley, the Earl of, Witley Court, Worcester.
Dunlop, Colin Robert, Glasgow.
Durham, the Earl of, Lambton Castle, Co. Durham.

Eastwood, Reuben, Victoria Iron Works, Derby.
Ellis, Thomas, Coatbridge, N.B.
Evans, William, Bowling Iron Works, Bradford, Yorkshire.

Farley, Reuben, Summit Foundry, West Bromwich.
Farnworth, William, Swindon Iron Works, Dudley.
Faviell, Jeremiah B., Campsmount, Doncaster.
Fell, Thomas, Springfield, Warrington.
Ferrie, William, Monkland Iron Works, Glasgow.
Firmstone, H. O., Leys Iron Works, Stourbridge.
Firth, Mark, Steel Manufacturer, Sheffield.
Fisher, E. K., Market Harborough.
Fletcher, W., West Cumberland Iron Company, Workington.
Forbes, David, F.R.S., 11, York Place, Portman Square, London, W.
Foster, W. O., Stourbridge Iron Works, Stourbridge.
Fothergill, R., (M.P.), Aberdare Iron Works, Aberdare.
Fowler, William, Sheepbridge Iron Works, Chesterfield.
Fox, Edwin, Carrifield House, Grimesthorpe Road, Sheffield.
Fox, C. Douglas, 6, Delahoy Street, Westminster, S.W.
Fox, Samuel, Stocksbridge, near Sheffield.
Fox, Theodore, Newport Rolling Mills, Middlesbrough.
Fry, Theodore, Rise Carr Rolling Mills, Darlington.

Galloway, Charles John, Knott Mill Iron Works, Manchester.
Gilkes, Edgar, Tees Side Iron Works, Middlesbrough.
Gilkes, Gilbert, Engineer, Middlesbrough.
Gill, William, Tees Side Iron Works, Middlesbrough.
Gjers, John, Ayresome Iron Works, Middlesbrough.
Goddard, Jno. H., Lane End Iron Works, Longton.
Goddard, William, Longton, Stoke-on-Trent.
Godfrey, Samuel, Middlesbrough Iron Works, Middlesbrough.
Goldwyer, John E., Bowling Iron Works, Bradford, Yorkshire.
Goodman, A., Newcastle-on-Tyne.
Gowen, Franklin B., President of Philadelphia and Reading Railroad, 227, South Forth Street, Philadelphia, U.S.A.
Granville, Earl, 16, Bruton Street, London, W.
Grazebrooke, Michael, Netherton Furnaces, Dudley.
Grazebrooke, Henry, jun., Stourbridge Iron Works, Stourbridge.
Greck, P., Russian Government Engineer, St. Petersburg, and 22, Blenheim Road, St. John's Wood, London, N.W.
Greenwood, Thomas, Albion Works, Leeds.
Greig, John, Coltness, Newmains, N.B.
Grier, W. M., 38, Blomfield Road, Maida Hill, London, W.
Griffiths, Jno., Altoft Hall, Normanton.
Griffiths, William, Derwent Tin Plate Works, Workington.
Grove, Edwin, Ebbw Vale Iron Company, 2, Laurence Pountney Hill London, E.C.
Grove, Edmund, Ormesby Foundry, Middlesbrough.

Hackney, William, Landore, Swansea.
Haggie, Peter, Gateshead-on-Tyne.
Haines, Richard, Church Lane, Tipton.
Hall, Sydney, Swansea.
Hampton, Thomas, Cyclops Works, Sheffield.
Hannay, Robert, jun., 43, West Regent Street, Glasgow.
Hanson, William, Britannia Iron Works, Middlesbrough.
Hardeman, Charles Henry, Clough Hall Iron Works, Kidsgrove.
Harrison, Thomas Elliott, Whitburn, near Newcastle-upon-Tyne.
Hartley, John, Shrubbery Iron Works, Wolverhampton.
Heath, Robert, Biddulph Iron Works, Stoke-on-Trent.
Heath, William, Biddulph Iron Works, Stoke-on-Trent.
Head, Charles A., Teesdale Iron Works, Stockton.
Head, Jeremiah, Newport Rolling Mills, Middlesbrough.
Head, Thomas Howard, 90, Cannon Street, London, E.C.

Heaton, John, 99, Cannon Street, London, E.C.
Henderson, William, 97, Buchanan Street, Glasgow.
Hewett, Edward Edwards, High Court, High Street, Sheffield.
Hewlett, Alfred, Kirkless Hall Iron Works, Wigan.
Hickman, George Haden, Groveland Iron Works, Tipton.
Higgins, Alfred, 1, St. Swithin's Lane, London.
Hill, Alfred C., Lackenby Iron Works, Middlesbrough.
Hill, J. C., Oakfields Iron Works, Newport, Monmouthshire.
Hill, Rowland, Acklam Terrace, Middlesbrough.
Hingley, Noah, Netherton Iron Works, Dudley.
Hirst, Thomas, Dowlais, Merthyr Tydvil.
Holcroft, James, Portfield Iron Works, Tipton.
Homer, Charles J., Chatterley Hall, Tunstall.
Hopkins, W. R. Innes, Tees Side Iron Works, Middlesbrough.
Hopkins, James Innes, 25, Laurence Pountney Lane, London, E.C.
Horton, Thomas E., Lilleshall Iron Works, Shifnal, Salop.
Hosgood, Thomas, Aberdare.
Hosking, Richard, Dalton-in-Furness.
Howson, R., Exchange Place, Middlesbrough.
Humphreys, A. W., 42, Pine Street, New York, U.S.A.
Hunter, James, Coltness Iron Works, Newmains, N.B.
Hunter, Charles L., Tredegar Iron Works, Newport, Monmouthshire.
Hunt, Augustus Henry, Birtley Iron Works, Chester-le-Street.
Hunt, James P., Corngreaves Iron Works, near Birmingham.
Hunter, John, Dalmellington Iron Works, by Ayr, N.B.
Hyde, Adam, Team Valley Iron Works, Gateshead.

Ianson, J. C. Rise Carr Rolling Mills, Darlington.
Ianson, Charles, jun., Royal Exchange, Middlesbrough.
Ingram, James, jun., Middlesbrough.

Jackson, Thomas, Coatbridge, N.B.
Jaffrey, G. W., Messrs. Tod and Macgregor's, Partick, near Glasgow.
James, John, Ebbw Vale Iron Works, Newport, Monmouthshire.
James, H. M., Parkend Iron Works, near Lydney.
Jaques, Richard Machell, Easby Abbey, Richmond, Yorkshire.
Jayne, Basil, Clydach, near Abergavenny.
Jeavons, Joshua, Millwall Iron Works, London, E.
Jeffries, E., Low Moor Iron Works, near Bradford, Yorkshire.
Jenkins, J. J., The Grange, Swansea.
Jenkins, William, Consett Iron Works, Blackhill, Co. Durham.
Johnson, C. G., Middlesbrough.

Johnson, Richard, 27, Dale Street, Manchester.
Johnson, Richard S., Sherburn Hall, Durham.
Johnson, Thewlis, 27, Dale Street, Manchester.
Jones, J. A., Ayrton Rolling Mills, Middlesbrough.
Jones, John, Iron Trade Offices, Middlesbrough.
Jones, Edwin, F., Normanby Iron Works, Middlesbrough.
Jones, William, Cyfarthfa Iron Works, Merthyr Tydvil.
Jones, Benjamin.
Jones, John, Dowlais Iron Works, Merthyr Tydvil.
Joseph, David, Rockleaze, Durdham Down, Bristol.

Kesteven, Thomas T., Shrubbery Iron Works, Wolverhampton.
Kirk, Henry, Iron Manufacturer, Workington.
Kirkconel, John, Cleator Moor, Carnforth, Lancashire.
Kitching, Alfred, Ironmaster, Darlington.
Kitson, James, jun., Monk Bridge Iron Works, Leeds.
Kitson, F. W., Monk Bridge Iron Works, Leeds.

Lancaster, John, (M.P.), Bilton Grange, Rugby.
Lawson, John, 3, Poets' Corner, Westminster, S.W.
Laybourne, Richard, Rhymney Iron Works, Tredegar.
Leigh, Joseph D., Patricroft, near Manchester.
Leonard, Moses, North British Iron Works, Coatbridge, N.B.
Leveson-Gower, Hon. F. E. (M.P.), 14, South Audley St., London, W.
Levick, Frederick, 8, Great Winchester-Street Buildings, London, E.C.
Levick, George, Grange Town Works, Cardiff.
Lewis, Lewis Thomas, Neath, Glamorganshire.
Lewis, H. W., Blaina Iron Works, Newport, Mon.
Lewis, William Thomas, Mardy, Aberdare.
Lloyd, Robert, Linthorpe Iron Works, Middlesbrough.
Lloyd, Francis H., Old Park Iron Works, Wednesbury.
Lloyd, Samuel, The Farm, Sparkbrook, Birmingham.
Lloyd, Wilson, Darlaston.
Longridge, William Smith, Alderwasley Iron Works, Ambergate, Derbyshire.
Longridge, R. B., Alderley Edge, Cheshire.
Longsdon, Robert, 4, Queen Street Place, London, E.C.
Longsdon, Alfred, Crown Buildings, Queen Victoria Street, London, E.C.

Macfarlane, Walter, Saracen Foundry, Glasgow.
Mackean, James, Ironmaster, Middlesbrough.
Malcolm, William, Seend Furnaces, near Melksham, Wiltshire.
Manby, Cordy, Dudley.

Markham, Charles, Staveley, Chesterfield.
Marley, John, Mining Engineer, Darlington.
Marten, Henry John, Parkfield Iron Works, Wolverhampton.
Marten, Edward Bindon, Stourbridge.
Martin, Edward P., Cwm Avon, Taibach, So. Wales.
Martin, Stephen, Junr., Clarence Steel Works, Sheffield.
Mason, Thomas, 25, Salthouse Road, Barrow-in-Furness.
Massicks, Thomas, Millom Iron Works, Cumberland.
Maynard, H. N., Viaduct Works, Crumlin, Newport, Monmouthshire.
McClelland, Andrew S., 140, St. Vincent Street, Glasgow.
McEwen, L. T., Lombard House, Lombard Street, E.C.
McLean, J. R., (M.P.), Great George Street, Westminster, S.W.
Menelaus, William, Dowlais Iron Works, Merthyr Tydvil.
Millington, Samuel L., Summerhill Iron Works, Tipton.
Mitchell, Charles, Walker, Newcastle-on-Tyne.
Monks, F., Whitecross Wire Company (Limited), Warrington.
Moffatt, George, 2, Laurence Pountney Hill, London, E.C.
Moreton, Edward, Barrow-in-Furness.
Morgan, H. L., Cwmbran, Newport, Monmouthshire.
Morley, George, Bridgend, Glamorganshire.
Morrison, H. M., Wellington Place, Longsight, Manchester.
Morrison, James, Rosedale and Ferryhill Iron Company, Newcastle-on-Tyne.
Morton, Robert, Stockton-on-Tees.
Muller, Charles Emile, Middlesbrough.
Murdock, William, Barrow Iron Works, Barrow-in-Furness.
Musgrave, Jno., Globe Iron Works, Bolton.
Musgrave, Joseph, Globe Iron Works, Bolton.

Neesham, George, South Bank Iron Works, Middlesbrough.
Neilson, Walter, 172, West George Street, Glasgow.
Neilson, John, Summerlee, Coatbridge.
Neilson, James, Mossend, Bellshill, N.B.
Neilson, William, Mossend, Bellshill, N.B.
Nelson, Thomas Bowstead, Engineer, York.
Nevill, W. H., Old Lodge Iron Works, Llanelly, Carmarthenshire.
Newall, Robert Stirling, Wire Rope Works, Gateshead.
Newmarch, William, F.R.S., London.
Norris, W. G., Coalbrookdale, Salop.

Oakes, Thomas, Alfreton Works, Derbyshire.

Page, Thomas, Roway Iron Works, West Bromwich.
Palmer, Charles M., Jarrow Iron Works, Newcastle-on-Tyne.
Parker, J. Spear, Cyclops Steel Works, Sheffield.
Parry, John, Ebbw Vale Iron Works, Newport, Monmouthshire.
Paterson, John, Harrington Iron Works, Cumberland.
Paton, John, Blaenavon Iron Works, Newport, Monmouthshire.
Pattinson, John, Newcastle-on-Tyne.
Peacock, Benjamin J., Cradley, near Brierley Hill.
Pearce, J., Abertillery Tin Plate Works, Newport, Monmouthshire.
Pearse, Mountjoy, Iron Shipbuilder, Stockton on-Tees.
Pearse, Jno. B., Harrisburg, Pennsylvania, U.S.A.
Pease, J. B., Tees Iron Works, Middlesbrough.
Pease, Joseph W., (M.P.), Hutton Hall, Guisbrough.
Penrose, William, Swansea.
Perry, Thomas, Highfields Works, Bilston.
Pigeon, D., Banbury.
Piper, Joseph, Cookley Iron Works, Kidderminster.
Plevins, Charles Henry, Newbold Iron Works, Chesterfield.
Plum, T. W., Old Park Iron Works, Shifnal, Shropshire.
Price, W., Royal Gun Factory, Woolwich, S.E.
Prosser, William, West Stockton Iron Works, Stockton-on-Tees.
Putnam, William, Darlington Forge, Darlington.

Radcliffe, James, Britannia Iron Works, Fence Houses.
Raine, Nicholas, South Hylton Iron Works, near Sunderland.
Ramsay, David Ramsay, Industrial Iron Co., Middlesbrough.
Ramsbottom, John, Harewood Lodge, Mottram, near Manchester.
Ramsden, James, Barrow Steel Works, Barrow-in-Furness.
Ramsden, W. G., Civil Engineer, Liverpool.
Ransome, Robert Charles, Ipswich.
Ratcliffe, James, Lancashire Steel Works, Gorton, Manchester.
Reay, Thomas M., Whitworth, Ferryhill.
Reed, E. J., Earle's Shipbuilding and Engineering Co., Hedon Road, Hull.
Reed, John H., 2, Pemberton Square, Boston, U.S.A.
Reynard, E. Horner, Sunderlandwich, near Driffield.
Richards, L., 13, Charlotte Street, Dowlais, Merthyr Tydvil.
Richards, J. J., Ebbw Vale Iron Works, Newport, Monmouthshire.
Richards, E. W., Ebbw Vale, Newport, Monmouthshire.
Richards, Edwin, Caldicot Iron Works, Chepstow, Monmouthshire.
Richards, E. M., (M.P.), Brooklands, Swansea.

Richards, Job, Park Gate Iron Works, Rotherham.
Richardson, Joseph, Stockton-on-Tees.
Richardson, Thomas, West Hartlepool Iron Works, West Hartlepool.
Richardson, W., Platt Brothers' Works, Oldham.
Ridley, J. C., Iron Works, Jarrow-on-Tyne.
Roberts, David, Taff Vale Iron Works, Pontypridd, Glamorganshire.
Robinson, J., Ebbw Vale Iron Company, 2, Laurence Pountney Hill, London, E.C.
Robinson, Walter, Whiston, Shifnal, Salop.
Robinson, John, Engineer, Atlas Works, Manchester.
Robson, Edward, Middlesbrough.
Roden, W. S., (M.P.), Shelton Bar Iron Works, Stoke-on-Trent.
Rogerson, John, Quayside, Newcastle-on-Tyne.
Roper, Richard S., Newport, Monmouthshire.
Rose, Henry Fullwood, Albert Iron Works, Moxley.
Round, B., Hange Furnaces, Tipton.
Rowley, Joseph, Blaina Iron Works, Newport, Monmouthshire.
Rummens, Francis, The Grove, Pinner, Middlesex.

Samuelson, B., (M.P.), Bodicote Grange, Banbury.
Sandberg, C. P., 19, Great George Street, Westminster, London, S.W.
Saunders, John, Cookley Iron Works, Kidderminster.
Scale, E. W., Merthyr Tydvil.
Schneider, Henry William, Barrow-in-Furness.
Sharp, Henry, Bolton Iron and Steel Works, Bolton.
Shaw, Matthew T., 144, Cannon Street, London.
Sheriff, A. T. A., Dean's Yard, Westminster, London, S.W.
Shield, Clifton, 43, Leazes Terrace, Newcastle-on-Tyne.
Siemens, C. W., 3, Great George Street, Westminster, London, S.W.
Smith, J. T., Hematite Steel and Iron Works, Barrow-in-Furness.
Smith, James, Workington Iron Works, Workington.
Smith-Shenstone, Frederick, Sutton Hall, Lewes, Sussex.
Smith, E. Fisher, The Priory Offices, Dudley.
Smith, John Stores, Sheepbridge Iron Works, Chesterfield.
Snelus, G. J., West Cumberland Iron Works, Workington.
Solly, N. Neal, Willenhall Iron Works, Willenhall.
Southan, Thomas, Muxton, near Newport, Salop.
Sparrow, Arthur, Penn, Wolverhampton.
Sparrow, W. M., Horsley Iron Works, Wolverhampton.
Sparrow, J. J., Bilston Mills, Bilston.
Spencer, Adam, Rolling Mills, West Hartlepool.

Spencer, John, Phœnix Iron Works, Coatbridge, N.B.
Spencer, Thomas, Blackladies, Brewood, near Penkridge.
Spencer, Thomas, The Grove, Ryton, Blaydon-on-Tyne.
Spencer, J. F., 28, Great George Street, Westminster, London, S.W.
Stephens, Frederick Cook, Al Cuidado de los Senores Ybarra e Cie., Bilbao, Spain.
Stevenson, John, Acklam Iron Works, Middlesbrough.
Stewart, Charles P., Atlas Works, Manchester,
Stoker, F. W., The Moor Iron Works, Stockton-on-Tees.
Summers, James W., Globe Iron Works, Staleybridge.
Swan, John G., Cargo Fleet Iron Works, Middlesbrough.
Swindell, J. E., Cradley Iron Works, Stourbridge.

Talbot, Edward E., The Grange, Carnforth, Lancashire.
Tate, John, Harrington, Cumberland.
Taylor, James, Richmond Terrace, Croft, Darlington.
Thomas, J. J., Britannia Iron Works, Middlesbrough.
Thompson, George, Winlaton, Blaydon-on-Tyne.
Thomson, George, Ruabon Iron Works, North Wales.
Thomson, J. M., Calder Iron Works, Glasgow.
Thomson, William, Railway Iron Works, Normanton.
Thompson, John, Clarence Iron Works, Middlesbrough.
Thorneycroft, Thomas, Tettenhall, Wolverhampton.
Tinn, Joseph, Ashton Rolling Mills, Bower Ashton, near Bristol.
Tosh, E. G., Chemical Laboratory, Whitehaven.
Tosh, George, North Lincolnshire Iron Works, near Brigg, Lincolnshire.
Trump, Henry Valentine, Rhymney Iron Works, Tredegar.

Udall, Thomas, Silverdale Iron Works, North Staffordshire.

Vaughan, Thomas, South Bank Iron Works, Middlesbrough.
Vaughan, Joseph, Market Place, Bishop Auckland.
Vickers, T. E., River Don Works, Sheffield.
Voss, J. M., Tin Works, Landore, Swansea.

Waddington, Joseph, Iron Foundry, Barrow-in-Furness.
Wadham, Edward, Dalton-in-Furness.
Walker, Alfred, York Railway Plant Co., York.
Walker, B., Engineer, Goodman Street Works, Leeds.
Walmsley, Thomas, Iron Manufacturer, Bolton.
Ward, Henry, Priestfield Works, Wolverhampton.
Ward, George, Bearnett House, Wolverhampton.

Webb, Henry A., Bretwell Hall Iron Works, Stourbridge.
Webb, Thomas S., 85, Gracechurch Street, London, E.C.
Westray, John, Barrow Steel Works, Barrow-in-Furness.
Wheeldon, Frederick R., 16, Waterloo Road, Wolverhampton.
Whitelaw, Alexander, Gartsherrie Iron Works, Coatbridge.
Whitham, J., Perseverance Iron Works, Leeds.
Whitwell, William, Thornaby Iron Works, Stockton.
Whitwell, Thomas, Thornaby Iron Works, Stockton.
Whitworth, Sir Joseph, Engineer, Manchester.
Wigram, Reginald, Steam Plough Works, Leeds.
Williams, Edward, Middlesbrough Iron Works, Middlesbrough.
Williams, Joshua, Aberdulais, Neath.
Williams, Nicholas, Hodbarrow Iron Ore Mines, Holborn Hill, Cumberland.
Williams, Richard, Brunswick Iron Works, Wednesbury.
Williams, Richard Price, 9, Great George Street, Westminster, S.W.
Williams, Walter, Wednesbury Oak Iron Works, Tipton.
Williamson, Hugh, Goldendale Iron Works, Tunstall.
Willman, Charles, Cleveland Hall, Middlesbrough.
Willans, Jacob G., 9, St. Stephen's Crescent, Bayswater, London. W.
Wilson, Isaac, Tees Side Iron Works, Middlesbrough.
Wilson, John Frederick, Tees Side Iron Works, Middlesbrough.
Wilson, George, Cyclops Steel Works, Sheffield.
Wilson, Alexander, Cyclops Steel Works, Sheffield.
Wilson, James, Darlington.
Wilson, George, Glaisdale Iron Works, via Yarm, Yorkshire.
Winby, W. E., Rabone Bridge Iron Works, Smethwick, near Birmingham
Wood, John, Maryport Hematite Iron Company, Maryport.
Woodall, Solomon, Windmill End Boiler Works, Dudley.
Woodcock, W. G., Eagle Works, West Bromwich.
Woodhouse, J. T., Midland Road, Derby.
Woodward, John, Queen Foundry, Ancoats, Manchester.
Wragge, Frederick, Shelton Bar Iron Works, Stoke-on-Trent.
Wright, E. T., Monmoor Iron Works, Wolverhampton.
Würzburger, Philipp, Mining Engineer, Dalton-in-Furness.

Ybarra, Senor Don José A. de, Bilbao, Spain.

STATISTICS OF THE IRON AND STEEL TRADES.

[It is requested that any inaccuracies in the following lists may be pointed out to the Editor.]

BLAST FURNACES.

CLEVELAND.

Place.	Name of Works.	Owners.	Furnaces. Built.	Furnaces. In blast.
Middlesbrough	Lackenby	Lackenby Iron Company	2	2
,,	Eston	Bolckow, Vaughan, and Co.	7	7
,,	South Bank	South Bank Iron Company	9	9
,,	Clay Lane	Clay Lane Iron Company	6	6
,,	Cargo Fleet	Swan, Coates, and Company	4	4
,,	Normanby	Jones, Dunning, and Company	3	3
,,	Ormesby	Cochrane and Company	3	3
,,	Tees	Gilkes, Wilson, Pease, and Co.	5	5
,,	Middlesbrough	Bolckow, Vaughan, and Co.	3	3
,,	Tees Side	Hopkins, Gilkes, and Company	4	4
,,	Linthorpe	Lloyd and Company	6	6
,,	Acklam	Stevenson, Jaques, and Company	4	4
,,	Ayresome	Gjers, Mills and Company	4	4
,,	Newport	B. Samuelson and Company	8	8
,,	Clarence	Bell Brothers	8	8
Stockton-on-Tees	Norton	Norton Iron Company	3	3
,,	——	Norwegian Titanic Iron Co.	2	2
,,	Thornaby	W. Whitwell and Company	3	3
,,	Stockton	Stockton Iron Furnace Company	3	3
,,	Carlton	Industrial Iron Company	2	2
Whitby	Grosmont	C. and T. Bagnall, jun.	2	2
,,	Glaisdale	George Wilson and Company	3	3
		Total	94	94

NORTH-EAST OF ENGLAND.

Place.	Name of Works.	Owners.	Furnaces. Built.	Furnaces. In blast.
Darlington	Middleton	George Wythes and Company	3	3
,,	South Durham	South Durham Iron Company	3	3
Ferryhill	Ferryhill	Rosedale and Ferryhill Iron Co.	8	8
,,	Tudhoe	Weardale Iron Company	2	2
Bishop Auckland	Witton Park	Bolckow, Vaughan, and Co.	5	5
,,	Towlaw	Weardale Iron Company	4	2
Consett	Consett	Consett Iron Company	5	3
Chester-le-Street	Birtley	Birtley Iron Company	3	0
Washington	Wear	Bell Brothers	1	1
Newcastle-on-Tyne	Jarrow	Palmer's Shipbuilding & Iron Co.	4	4
,,	Elswick	Sir W. Armstrong and Company	2	2
,,	Walker	Losh, Wilson, and Bell	2	1
Seaham	Seaham	Watson, Kipling and Co.	1	1
		Total	43	35

The Lackenby Iron Company are building one new furnace.
Cochrane and Company are building one new furnace.
Rosedale and Ferryhill Company are building two new furnaces.
The Consett Iron Company are building one new furnace.
William Whitwell and Company are building two new fnrnaces.
The North of England Industrial Iron Company are building one new furnace.
The Tees Bridge Iron Company are building two new furnaces.
Thomas Richardson and Sons are building two new furnaces.
Downey and Company are building two new furnaces at Coatham.
Robson, Maynard, and Company are about to erect two new furnaces at the Redcar Iron Works, Coatham.

NORTH-WEST OF ENGLAND.

Place.	Name of Works.	Owners.	Built.	In blast.
Wigan	Wigan	Wigan Coal and Iron Co., Lim.	10	9
Ditton	Ditton	Ditton Iron Company	4	4
Carnforth	Carnforth	Carnforth Hematite Iron Co., Ld.	5	5
Barrow	Barrow	Barrow Hematite Steel Co., Ld.	12	11
Millom	Millom	Cumberland Iron Mining and Smelting Company, Limited	5	4
Askam	Askam	Furness Iron and Steel Co., Ld.	3	3
Whitehaven	Cleator	Whitehaven Hematite Iron Co.	6	5
,,	Lonsdale	Lonsdale Iron Company	1	1
Harrington	Harrington	Bain, Blair, and Paterson	4	4
Workington	Workington	Workington Iron Company	6	4
,,	West Cumberland	Hematite Iron Co., Limited	5	4
Maryport	Maryport	Maryport Hematite Iron Co.	4	4
,,	Solway	Solway Iron Company	2	
		Total	67	60

The Solway Hematite Company are building two furnaces.
The Moss Bay Hematite Iron Company are building two furnaces at Workington.
The Ditton Iron Company are building two furnaces.
The Maryport Hematite Iron Company are building one furnace.
The Barrow Rolling Mills Company are building one new furnace.
The Lonsdale Iron Company are building one new furnace.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE.

Wolverhampton	Chillington	Chillington Iron Company	4	2
,,	Parkfield	Parkfield Iron Company	5	3
,,	Millfields	...	4	0
,,	Priestfields, New	W. Ward and Sons	2	2
,,	Osier Bed	Osier Bed Iron Company	3	1
,,	Stow Heath	W. and J. S. Sparrow	4	2
,,	Willenhall	Fletcher, Solly, and Urwick	3	2
,,	Moseley Hole	Chillington Iron Company	3	0
Bilston	Bilston Brook	Bilston Brook Furnace Company	3	2
,,	Herbert's Park	D. Jones	1	1
,,	Barbor's Field	Barbor's Field Iron Company	2	2
,,	Caponfield	J. Bagnall and Sons	3	1
,,	Spring Vale	A. Hickman	2	1
,,	Deep Fields	Deepfields Iron Company	3	2
,,	Coseley	J. Turley	2	2

Place.	Name of Works.	Owners.	Built.	In blast.
Bilston	Priorfields	H. B. Whitehouse	3	3
,,	Stonefield	Stonefield Iron Company	1	1
,,	Bradley	G. B. Thorneycroft and Co.	2	2
,,	Bouvereux	Tame Iron Company	2	1
Wednesbury	Rough Hay	Addenbrooke, Smith, & Pidcock	3	3
,,	Old Park	Patent Shaft and Axle Company	3	3
,,	Broadwaters	S. Groucutt and Sons	3	3
,,	Darlaston	Darlaston Iron and Steel Co.	3	2
,,	Moxley	David Rose	2	2
Tipton	Wednesbury Oak	P. Williams and Sons	3	2
,,	Willingsworth	Willingsworth Iron Company	2	2
,,	Tipton	...	3	0
,,	Tipton Green	W. Roberts and Company	4	4
,,	Coneygree	Earl of Dudley	3	2
,,	Park Lane	J. Colbourn and Sons	2	1
,,	Horseley	J. Colbourn and Sons	2	2
,,	Groveland	G. Hickman	1	1
,,	Tividale	Round Brothers	2	2
,,	Dudley Port	...	2	0
,,	Do.	J. and C. Oinons	1	1
West Bromwich and Oldbury	Gold's Hill	J. Bagnall and Sons	3	2
,,	Union	P. Williams and Company	3	2
,,	Stour Valley	J. and C. Onions	2	2
,,	Crookhay	W. and G. Firmstone	4	2
,,	Oldbury	J. and S. Onions	4	0
Walsall	Birchills	Williams Brothers	2	0
,,	Hatherton	W. Thomas	2	1
,,	Birchills, New	J. Brayford	4	1
,,	Bentley	Chillington Iron Company	2	1
,,	Pelsall	B. Bloomer and Son	2	2
,,	Green Lanes	John Jones	2	2
West of Dudley	Corngreaves	New British Iron Company	6	4
,,	Withymoor	W. H. Dawes	2	2
,,	Netherton	N. Hingley and Sons	2	2
,,	Windmill End	J. H. Pearson	3	2
,,	The Level	Earl of Dudley	4	2
,,	Netherton, New	M. and W. Grazebrook	2	2
,,	Woodside	Cochrane and Company	3	3
,,	Old Level	I. Holcroft	3	1
,,	Shut End	J. Bradley and Company	4	3
,,	Corbyn's Hall, New	New Corbyn's Hall Iron Co.	4	0
,,	Corbyn's Hall	W. Matthews	4	2
,,	The Leys	W. and G. Firmstone	3	2
,,	Parkhead	Evers and Martin	2	2
,,	Old Hill	D. Rose	2	1
,,	Buffery	John Jones	1	1
		Total	166	104

NORTH STAFFORDSHIRE.

Place.	Name of Works.	Owners.	Built.	In blast.
Biddulph ...	Biddulph Valley ...	Robert Heath and Son ...	4	4
Norton-in-the-Moors	Norton ...	Do. do. ...	4	4
Kidsgrove ...	Clough Hall	Kinnersley and Company	4	4
Stoke-on-Trent ...	Fenton Park	... ...	2	0
Tunstall ...	Goldendale	Williamson Brothers ..	4	3
,, ...	Chatterley	Chatterley Iron Company	2	2
Longton ...	Lane End ..	Thomas Goddard and Sons	3	3
Stoke-on-Trent	Shelton ...	Earl Granville	8	8
Newcastle ...	Silverdale ...	Stanier and Company ...	4	3
,, ...	Apedale ...	Do. ...	5	5
Kidsgrove ...	Talke ...	North Staffordshire Iron Co.	2	2
		Total	42	38

SHROPSHIRE.

Place.	Name of Works.	Owners.	Built.	In blast.
Wellington	Dark Lane Hinkshay	Leighton Grenfell ...	4	3
,,	Dawley Castle Lawley ... Lightmoor ...	Coalbrookdale Company	2 1 2	1 0 2
,,	Ketley . .	Ketley Company ...	1	1
Shifnal ...	Lodge Wood Prior Lee ...	Lilleshall Iron Company	9	8
Wellington	Madeley Wood	Madeley Wood Company	3	3
,,	Madeley Wood	W. O. Forster	4	2
Shifnal ...	Old Park ...	Old Park Iron Company	4	2
		Total	30	22

YORKSHIRE—SOUTH, AND WEST RIDING.

Place.	Name of Works.	Owners.	Built.	In blast.
Leeds ...	Beeston Manor	A. Harding and Company	3	2
Bradford ...	Bowling ...	Bowling Iron Company...	6	5
Elsecar ...	Elsecar ...	W. H. and George Dawes	4	4
Milton ...	Milton ...	Do. do.	2	2
Leeds ...	Farnley ...	The Farnley Iron Company	4	3
Masbro' ...	Holmes ...	Parkgate Iron Company, Lim.	3	3
Bradford ...	Low Moor ...	Hird, Dawson, and Hardy	8	7
Chapeltown	Thorncliffe	Newton, Chambers, & Company	3	3
Worsborough	Worsborough	Worsborough Iron Company ...	1	1
Leeds ...	York Road	R. and W. Garside ...	3	2
Sheffield ...	Hepworth ...	Hepworth Iron Company	2	1
,, ...	Brightside ...	Cooke and Company ...	2	2
,, ...	Atlas ...	Sir Jno. Brown & Co., Lim.	2	2
,, ...	Cyclops ...	Cammell & Co., Lim. ...	1	1
Rotherham	Parkgate ...	Parkgate Iron Company, Lim.	1	1
,,	Hazlehead...	Hazlehead Iron Company	2	0
Leeds ...	West Ardsley	West Yorkshire Iron & Coal Co.	5	3
,, ...	Hunslet ...	Aireside Hematite Iron Co.	2	2
		Total	54	44

The Thorncliffe Company (Messrs. Newton, Chambers, & Co.) are erecting one furnace, which is nearly completed.

The Parkgate Company intend to build two at Parkgate.

The West Yorkshire Iron and Coal Company are erecting two furnaces, which will be in operation in July.

Messrs. Brown, Bailey, and Dixon are erecting works at Carbrook, near Sheffield, which will include blast, puddling, and Bessemer furnaces, and will cover upwards of 30 acres.

DERBYSHIRE.

Place.	Name of Works.	Owners.	Built.	In blast.
Alfreton ...	... Alfreton ...	... J, Oakes and Company ...	... 3	... 2
Butterley ...	... Butterley ...	... The Butterley Company	... 7	... 6
Clay Cross ...	... { Clay Cross, Codnor }	... ... The Clay Cross Company	... 3	... 2
Denby ...	... Denby ...	... W. H. and George Dawes	... 4	... 4
,, ...	... Morley Park	... C. C. Disney	... 2	... 2
,, ...	... Newbold ...	... Newbold Iron Company	... 1	... 1
,, ...	... Oakerthorpe	... Oakerthorpe Iron & Coal Co., Lim.	2	... 1
,, ...	... Renishaw	... James Morrison	... 5	... 5
Chesterfield	... Sheepbridge	... Sheepbridge Coal & Iron Co., Lim.	5	... 4
,,	... Stanton ...	... The Stanton Iron Works Co. ..	6	... 5
,,	... Staveley ...	... Staveley Coal & Iron Co., Lim.	6	... 6
,,	... West Hallam	... H. B. Whitehouse & Sons	... 3	... 2
,,	... Wingerworth	... Wingerworth Iron Company ...	4	... 2
		Total	... 51	... 42

The Staveley Coal and Iron Company, Limited, are erecting one furnace.

Messrs. New and Co., of Nottingham, and Mr. Heywood of Derby, are erecting furnaces, three in all, near Ilkeston, on the Erewash Valley Line.

Messrs. G. Wilson and Cammell are erecting large works at Dronfield, which will comprise blast and puddling furnaces.

NORTHAMPTON AND LINCOLNSHIRE.

Wellingborough ...	East End ...	... T. Butlin and Company	... 4	.. 4
Weedon ...	... Heyford ...	... Plevins and Company ...	... 3	... 3
Heyford ...	... Heyford ...	... Do. do. ...	... 5	... 3
,, ...	... Stowe ...	... Castle Dykes Iron Company	... 2	... 0
Finedon ...	... Finedon ...	... Glendon Iron Company	... 3	... 3
Brigg ...	... Trent ...	... W. H. and G. Dawes ...	... 3	... 2
,, ...	... Frodingham	... Frodingham Iron Company	... 4	... 3
,, ...	.. N. Lincolnshire	... N. Lincolnshire Iron Co.	... 2	... 1
		Total	... 26	... 19

Messrs. W. H. and G. Dawes are building four new furnaces.

GLOUCESTERSHIRE, WILTSHIRE, AND SOMERSETSHIRE.

Forest of Dean	... Cinderford	... Henry Crawshay and Company	4	... 3
,,	... Oakwood ...	.. Ebbw Vale Iron Company	... 1	... 0
,,	... Park End, Lydney ...	Forest of Dean Iron Company ...	3	... 2
,,	... { Soudley, Newnham ... }	Goold Brothers	... 2	... 1
Westbury ...	... Westbury ...	... Westbury Iron Co., Limited ...	4	... 3
Seend ...	.. Seend ...	... Malcolm and Company	... 3	... 2
Bristol ...	... Ashton Vale	... Ashton Vale Iron Co., Lim. ...	1	... 1
		Total	... 18	12

NORTH WALES.

Brymbo ...	... Brymbo ...	... Brymbo Iron Company ...	... 3	... 2
Ffrwd ...	... Ffrwd ...	... Sparrows and Poole ...	... 3	... 2
Plakynaston	... Plakynaston	... Buckley, Newton, and Co.	... 1	... 0
Ruabon ...	... Ruabon ...	... New British Iron Company	... 3	... 1
Mostyn ...	... Mostyn ...	... Mostyn Iron Company ...	... 2	... 2
		Total	... 12	... 7

Lancaster & Company are building two furnaces at Mostyn.

MONMOUTHSHIRE AND SOUTH WALES.

Place.	Name of Works.	Owners.	Built.	In blast.
Abersychan		Ebbw Vale Company	6	5
Ebbw Vale		Do. do.	3	2
Victoria		Do. do.	3	2
Sirhowey		Do. do.	4	4
Pontypool		Do. do.	3	3
Nant-y-Glo		J. and C. Bailey	6	6
Blaenavon		Iron Company	9	8
Beaufort		...	6	6
Blaina		Blaina Iron and Coal Co.	2	0
Cwm Celyn		Do. do.	3	2
Coalbrook Vale		Do. do.	1	1
Cwm Bran		Roper and Company	2	2
Rhymney, 6; Bute, 3		Rhymney Company	9	7
Tredegar		Tredegar Iron Company	9	6
		Total	66	54
Glamorgan	Aberaman	Powell Duffryn	3	0
,,	Abernant	Abernant Iron Company	2	2
,,	Llwydcoed	Do. do.	3	2
,,	Plymouth	R. Fothergill & Co.	3	3
,,	Duffryn	Do.	3	3
,,	Penydarran	Do.	7	0
,,	Brynna	—	1	0
,,	Briton Ferry	Townsend, Wood, & Co.	2	1
,,	Cwm Avon	Governor & Co. of Copper Miners	7	3
,,	Cyfarthfa	R. T. Crawshay	5	5
,,	Ynisvach	Do.	4	4
,,	Cefn Cwsk	Forester and Co.	4	0
,,	Dowlais	Guest and Co.	17	16
,,	Gadlys	Wayne and Co.	4	2
,,	Llynvi	Llynvi Iron Company	4	4
,,	Maesteg	Do.	3	0
,,	Pentyrch	Booker and Company	2	2
,,	Pontardawe	Lewis and Sons	1	0
,,	Tondu	Brogden and Sons	2	2
,,	Treforest	F. Crawshay	3	0
,,	*Ystalyfera	Budd and Co.	11	6
,,	*Venalt	W. Gregory	2	0
		Total	93	55
Brecon	*Yniscedwyn	Iron Company	2	2
,,	*Onllwyn, Neath	Do.	2	0
,,	Hirwain	—	4	0
,,	Beaufort	J. and C. Bailey	7	6
,,	Clydach	Basil Jayne	4	0
		Total	19	8
Carmarthenshire	*Bryn Amman	Amman Iron Company	3	3
,,	Gwendreath	D. Watney	3	0
,,	Trimsaran (Gwendreath)		2	0
Pembroke	*Kilgetty	Vickerman and Co.	2	0
		Total	10	3

The Blaenavon Company are building one new furnace. * Use anthracite coal.

SCOTLAND.

Place.	Name of Works.	Owners.	Built.	In blast.
Glasgow	Gartsherrie	Messrs. W. M. Baird & Co.	16	13
,,	Coltness	Coltness Iron Company	12	12
,,	Summerlee	Wilson and Company	8	7
,,	Langloan	Robert Addie	8	7
,,	Govan	W. Dixon	5	5
,,	Calder	W. Dixon	8	6
,,	Carnbroe	Merry and Cuninghame	6	6
,,	Shotts	Shotts Iron Company	4	4
,,	Castle Hill	Shotts Iron Company	3	2
,,	Wishaw	Wishaw Iron Company	3	2
,,	Calderbank	Monkland Iron and Steel Co.	6	5
,,	Chappelhall	Monkland Iron and Steel Co.	3	3
,,	Clyde	Colin, Dunlop, and Co.	6	5
,,	Clyde (Quarter)	Colin, Dunlop, and Co.	4	4
East Coast	Kinneil	George Wilson and Company	4	3
,,	Almond	James Russel and Son	3	2
,,	Carron	Carron Iron Company	4	3
,,	Lochgelly	Lochgelly Iron Company	4	2
,,	Lumphinnans	Lumphinnans Iron Company	2	1
,,	Bridgeness	... ...	2	1
West Coast	Eglinton	W. Baird and Company	8	7
,,	Lugar	Do. do.	4	4
,,	Muirkirk	Do. do.	3	3
,,	Portland	Do. do.	6	4
,,	Dalmellington	Dalmellington Iron Company	8	7
,,	Glengarnock	Glengarnock Iron Company	14	12
		Total	154	130

ABSTRACT OF TABULAR STATEMENTS.

	Built.	In blast.
Cleveland	94	94
North East of England	43	35
North West of England	67	60
South Staffordshire	166	104
North Staffordshire	42	38
Shropshire	30	22
Yorkshire—South and West Riding	54	44
Derbyshire	51	42
Northampton and [illegible]	26	19
Gloucester, Wilts, &c.	18	12
North Wales	12	7
South Wales and Monmouth	188	120
Scotland	154	130
Total	945	727

CHARCOAL FURNACES.

		Built.		In blast.
Newland furnaces, hot blst—charoal $\frac{4}{5}$, coke $\frac{1}{5}$	Harrison, Ainslie & Co. (Lancashire)	1	...	1
Backbarrow furnace, cold blast—charcoal	Do. do. ...	1	...	1
Duddon furnace, cold blast—charcoal ...	Do. (Cumberland)	1	...	0
Bonawe furnace, cold blast—charcoal ...	Do. (Lorn, Argyleshire)	1	...	0
Warsash furnace, cold blast—charcoal ...	Do. (Hampshire)	1	...	1
		5	...	3

MILLS AND FORGES.

NORTH OF ENGLAND.

Place.	Name of Works.	Owners.	No. of Puddling Furnaces.
Middlesbrough ...	Middlesbrough ...	Bolckow, Vaughan, & Co., Lim. ...	67
,, ...	Tees Side ...	Hopkins, Gilkes, & Co., Lim. ...	100
,, ...	Newport	Fox, Head, and Company	40
,, ...	Imperial	Jackson, Gill, and Company ...	32
,, ...	West Marsh ...	West Marsh Iron Company	20
,, ...	Britannia	Britannia Iron Company, Lim. ...	120
,, ...	Ayrton	Jones Brothers and Company ...	21
Stockton ...	North Yorkshire ...	N. Yorkshire Iron Company, Lim.	59
,, ...	Thornaby	W. Whitwell and Company ...	33
,, ...	Westbourne ...	J. Holdsworth and Company ...	21
,, ...	Malleable	Stockton Malleable Iron Company, Lim.	58
,, ...	Rail Mill	Stockton Rail Mill Company, Lim....	70
,, ...	West Stockton ...	West Stockton Iron Company, Lim.	23
,, ...	Bowesfield... ...	Bowesfield Iron Company, Lim. ...	30
,, ...	Richmond	R. Jaques and Company	6
,, ...	Moor	Shaw, Johnson, and Reay	20
Darlington ...	Albert Hill ... Springfield ...	Darlington Iron Company	190
,, ...	Skerne	Pease, Hutchinson, and Company ...	58
,, ...	Rise Carr	Fry, Ianson, and Company ...	32
,, ...	Whessoe	T. Vaughan	36
Ferry Hill ...	Tudhoe	Weardale Iron and Coal Company, Lim.	56
Bishop Auckland ...	Witton Park ...	Bolckow, Vaughan, & Co., Lim. ...	101
,, ...	Bishop Auckland ...	Thomas Vaughan	30
Consett ...	Consett	Consett Iron Company, Lim. ...	151
Chester-le-Street ...	Birtley	Birtley Iron Company	6
Fence Houses ...	Britannia	Hopper, Radcliffe, and Company ...	41
Sunderland ...	Monkwearmouth ...	S. Tyzack and Company	32
,, ...	Wear	Oswald and Company	80
,, ...	South Hylton ...	Raine Bros.	12
Hartlepool ...	Hartlepool ...	Hartlepool Malleable Iron Co. ...	32
,, ...	West Hartlepool ...	T. Richardson and Sons	109
,, ...	Stranton	Stranton Iron and Steel Co. ...	20
Newcastle-on-Tyne	Walker	Losh, Wilson, and Bell	57

Place.	Name of Works.	Owners.	No. of Puddling Furnaces.
Jarrow-on-Tyne	Jarrow ...	... Palmer's Shipbuilding and Iron Co., Ld.	70
,, ...	Hive ...	... J. Elliott	13
Gateshead ...	Gateshead	... Hawks, Crawshay, and Sons	69
,, ...	Park ...	... J. Abbott and Company, Limited ...	32
,, ...	Felling ...	... The Felling Iron and Coal Company, Ld.	23
,, ...	Team Valley	... T. Abbott	20
		Total	1,990

NORTH WEST OF ENGLAND.

West Cumberland	Workington	... W. Cumberland Hematite Iron Co., Ld.	40
,, ...	,,	... Kirk Brothers and Company	16
,, ...	,,	... Kirk and Valentine	8
,, ...	,,	... Price Brothers	2
Maryport ...	Ellen	... Ellen Rolling Mills Company, Limited...	9
		Total	75

YORKSHIRE—WEST RIDING.

Leeds ...	... Albert ...	... W. T. Bolland and Drury	23
,, ...	... Clarence	... Taylor Brothers and Company	17
,, ...	... Farnley	... Farnley Iron Company	24
,, ...	... Kirkstall Forge	Kirkstall Forge Company	24
,, ...	... Leeds ...	... S. T. Cooper and Company	13
,, ...	... Monkbridge	... Monkbridge Iron Company	26
,, ...	... Perseverance	... J. Witham and Son	32
,, ...	... Thornhill	... Monkbridge Iron Company	12
,, ...	... Hunslet	... Tyers, Middleton, and Company ...	13
Bradford	... Bowling	... Bowling Iron Company	29
,,	... Low Moor	... Hird, Dawson, and Hardy	40
,,	... Water Lane	... James Perkins	2
Wakefield	... Calder Vale	... Samuel Whitham	30
Normanton	...Railway Iron Works	W. Thomson and Company	20
		Total	305

SOUTH YORKSHIRE.

Sheffield	... Atlas ...	... John Brown and Company, Limited ...	78
,,	... Wortley	... Andrews, Burrows, and Company ...	11
,,	... Cyclops	... C. Cammell and Company, Limited ...	56
,,	... Cardigan	... Cardigan Iron Company	12
Rotherham	... Elsecar and Milton	W. H. and George Dawes	30
,,	... Parkgate	... Parkgate Iron Company, Limited ...	84
,,	... Midland	... Midland Iron Company, Limited ...	28
,,	... Northfield	.. Neill, Edgar, and Johnson	18
,,	... Masbro' Forge	... G. and J. Brown	12
,,	... Swinton ...	... Sir Jno. Brown & Company, Ld. (Sheffield)	20
		Total	349

DERBYSHIRE.

Place.	Name of Works.	Owners.	No. of Puddling Furnaces.
Alfreton...	... Butterley	... The Butterley Company	46
Chesterfield	... Whittington	... T. Firth and Sons	18
,,	... Sheepbridge	... Sheepbridge Coal and Iron Co., Limited	*27
Derby ...	... Railway	... Eastwood, Swingler, and Company ...	14
,, ...	... Victoria	... Eastwood, Swingler, and Company ...	25
		Total	130

* 9 double furnaces worked by mechanical power, and equal to 27 ordinary furnaces.

SOUTH STAFFORDSHIRE.

Bilston ...	... Bank Field ... Bradley ...	S. Groucutt and Sons	45
,, ...	... Batman's Hill ...	W. Rose	11
,, ...	... Bilston Mill ...	W. and J. S. Sparrow and Company ...	26
,, ...	... BradleyTinPlate...	Thompson, Hatton, and Company ...	8
,, ...	... Bradley... ...	... ...	9
,, ...	... Bradley, New ...	Gittings and Austin	8
,, ...	... Deepfields ...	... ...	10
,, ...	Bridge, Herbert's Park..	David Jones and Sons	29
,, ...	... Millfield ...	Union Coal and Iron Company, Limited	23
,, ...	... Britannia ...	Brereton and Company	9
,, ...	... Regent ...	Regent Iron Company	10
,, ...	... Stonefield ...	Bilston Iron Company	12
,, ...	... Ettingshall ...	Morewood and Company	12
,, ...	... Ebenezer ...	Standing	10
Wolverhampton	Lanesfield ...	... ...	19
,, ,, ,,	Chillington Capponfield, Bilston, Leabrook, ...	Chillington Iron Company	66
,,	Cleveland, Monmore	E. T. Wright	19
,,	Horseley Fields	Osier Bed Iron Company	24
,,	Minerva ...	Isaac Jenks...	14
,,	Shrubbery, Swan Gardens ...	G. B. Thorneycroft and Co....	74
Willenhall	... Monmore Lane...	H. Deakin & Co.	11
Wednesbury	... Bull's Bridge ...	Molineux and Co.	10
,,	... Darlaston Green	Darlaston Iron and Steel Co., Limited...	22
,,	... King's Hill ...	Darlaston Iron and Steel Co., Limited...	11
,,	... Victoria, Moxley	David Rose	8
,,	... Albert, Moxley...	David Rose	22
,,	... Monway... ...	J. Marshall	11
,,	... Old Park ...	Patent Shaft and Axle Company ...	32
,,	... Brunswick ...	Do. Do.	54
,,	... Moxley ...	David Rose	10
,,	... ,, ...	Thomas Wells	22
Walsall	... Walsall	Skelton and Yardley	18
,,	... Victoria... ...	Mills, Henry, and Sons	7
,,	Wedge's Mills, Cannock ..	W. Gilpin, sen., and Company	8
,,	... Birchills ...	J. Bissell & Son	6
,,	... New Birchills ...	New Birchills Company	12

Place.	Name of Works.	Owners.	No. of Puddling Furnaces.
Walsall	New Birchills	Bunce, Jones, and Company	10
,,	Pelsall	B. Bloomer & Son	26
,,	Cyclops	E. Russell	22
West Bromwich	Gold's Hill	John Bagnall and Sons	75
,,	Imperial		
,,	Leabrook		
,,	Gold's Hill, New	T. Davis	12
,,	Albion	Albion Sheet Iron Company	8
,,	Albion	Britannia Iron Company	10
,,	Atlas	Israel Parks	15
,,	Brick House	R. Williams and Son	8
,,	Bromford	J. Dawes and Sons	69
,,	Hall End	J. T. and W. E. Johnson	9
,,	Church Lane	Standing	11
,,	Crookhay	W. and G. Firmstone	20
,,	Witton's Lane	Roberts, Tonks, and Company	5
,,	Excelsior	Allen and Company	8
,,	Eagle	Eagle Coal and Iron Company	14
,,	Staffordshire	...	10
,,	Great Bridge	Standing	10
,,	Victoria, Swan Village	D. Hipkins and Sons	8
,,	Ridgacre	Assignees, of S. Whitehouse and Sons	20
,,	Wellington	Lees and Holden	11
,,	Roway	E. Page and Sons	16
,,	Spon Lane	Patent Nut and Bolt Company	11
,,	Providence	Bridge, Gill, and Bridge	16
,,	Dunkirk	Jordan and Company	4
,,	Waterloo	Waterloo Iron Company	12
,,	Bradford	Bradford Iron Company	8
Smethwick	Gun Barrel	W. Marshall	4
,,	Anchor	J. Baston	7
,,	Cape	Benjamin Richards	7
,,	Smethwick	J. Stone	3
,,	Cape	W. R. Brooks	4
,,	Crown	T. L. Nicklin	10
,,	London Works	Patent Nut and Bolt	9
,,	Regent	Beard and Eberhardt	10
,,	District	District Steel and Iron Company	22
,,	Rabone Bridge	Rabone Bridge Iron Company	10
Oldbury	Brades	Hunt and Sons	12
,,	Britannia	Bright, Perry, and Gettings	13
,,	Eagle	F. Simpson and Company	10
Tipton	Bloomfield	W. Barrows and Son	89
,,	Factory		
,,	Tipton Green		
,,	Globe and Tividale	J. P. Hanes	9
,,	Groveland	G. Hickman	24
,,	Great Bridge, Lea Brook	Great Bridge Iron and Steel Company, Limited	22
,,	Gospel Oak	Gospel Oak Iron Company	24
,,	Sheepwash Lane	Standing	10
,,	Summer Hill	W. Millington and Company	16
,,	Tipton	Standing	22

Place.	Name of Works.	Owners.	No of Puddling Furnaces.
Tipton ...	Wednesbury Oak	P. Williams and Sons	32
,, ...	Dudley Port ...	... ...	8
Dudley	Portfield ...	James Holcroft	16
,, ...	Dudley Port ...	Plant and Fisher	26
,, ...	Netherton ...	Hingley and Sons	29
,, ...	Dixon's Green	Frederick Cresswell	11
,, ...	Corbyn's Hall ...	Corbyn's Hall Iron Company	40
,, ...	Swindon ...	E. P. and W. Baldwin	12
Brierley Hill ...	Brockmore Tinplate	Budd and Company	18
,, ...	Hart's Hill ...	Hingleys and Smith	33
,, ...	Level	H. Hall	18
,, ...	Round Oak ...	Earl of Dudley	54
,, ...	Brierley Corngreaves	New British Iron Company	63
,, ...	Wellington ...	T. Webb and Sons	11
,, ...	The Lays ...	Brown and Freer	33
,, ...	Cradley Forge	S. Evers and Sons	16
Stourbridge ...	Brettel Lane ...	Brettel Lane Iron Company	16
,, ...	Stourbridge Brierley Shutt End	John Bradley and Company	59
,, ...	Whittington ...	J. Williams and Company	9
,, ...	Hyde ...	Lee and Bolton	20
Kidderminster ...	Cookley ...	J. Knight and Company	20
,, ...	Broadwaters ...	Thompson, Hatton and Company ...	11
,, ...	Wilden ...	E. P. and W. Baldwin	7
		Total	2,049

NORTH STAFFORDSHIRE.

Place.	Name of Works.	Owners.		No of Puddling Furnaces.
Tunstall ...	Ravensdale ...	Robert Heath and Son	54	134
Biddulph ...	Biddulph ...	,, ,, ...	40	
Norton-in-the-Moors...	Norton ...	,, ,, ...	40	
Tunstall ...	Chesterton ...	Edward C. Peake		24
Kidsgrove ...	Clough Hall ...	Kinnersly and Company		74
Stoke-upon-Trent	Shelton ...	Shelton Bar Iron Company		90
,,	Cliff Vale ...	J. Bull and Son		20
,,	Berry Hill ...	W. Bowers		22
Newcastle-under-Lyne	Silverdale Knutton	Stanier and Company		56
Kidsgrove ...	Wheelock ...	Wheelock Iron and Salt Company ...		24
		Total		444

SHROPSHIRE.

Place.	Name of Works.	Owners.	No of Puddling Furnaces.
Wellington ...	Horsehay ...	Coalbrookdale Iron Company	42
,, ...	Stirchley ...	Leighton and Grenfell	30
,, ...	Ketley ...	Ketley Iron Company	20
,, ...	Trench ...	late Trench Iron Company (standing)	—
,, ...	Trench ...	Shropshire Iron Company	14
,, ...	Wombridge ...	Wombridge	9

Place.	Name of Works.	Owners.	No. of Puddling Furnaces.
Wellington ...	Lawton ...	late Lawton Iron Company (standing)	
,, ...	Heybridge ...	Heybridge Company	10
Shiffnall ...	Old Park ...	Old Park Iron Company ... (standing)	30
,, ...	Snedshill ...	Snedshill Iron Company	35
,, ...	Hollinswood ...	Eagle Iron Company, Limited	16
		Total	206

SOMERSETSHIRE.

Bristol ...	Bower Ashton...	Joseph Tinn	9

LANCASHIRE.

Manchester ...	Pendleton ...	W. Barningham	19
,, ...	Ashbury... ...	Ashbury Carriage and Iron Company ...	22
,, ...	,, ...	Maybury, Matthews, and Company ...	8
,, ...	Bradford ...	Richard Johnson and Nephew	20
,, ...	Gorton ...	Manchester, Sheffield, and Lincolnshire Railway Works	9
Staleybridge ...	Globe ...	John Summers	9
Ashton-under-Lyne	Parkbridge ...	Hannah Lees and Sons	5
Oldham ...	Hartford ...	Platt Brothers, and Company	7
Bolton ...	Bolton-le-Mooors	Bolton Iron and Steel Company... ...	6
,, ...	Atlas Forge ...	Thomas Walmsley	16
Warrington ...	Dallam	Dallam Forge Company, Limited ...	29
,, ...	Bewsey ...	Warrington Wire Iron Company, Limited	40
,, ...	Whitecross Wire Works	Whitecross Wire Company, Limited ...	13
Preston ...	Preston	North of England Carriage and Iron Company, Limited	33
Wigan ...	Albion	Hall and Matthews...	14
,, ...	——	Dallam Forge Company	31
,, ...	Ince	Ince Hall Rolling Mills Company ...	12
Liverpool ...	Mersey	Mersey Iron and Steel Company, Limited	8
,, ...	Garston	Liverpool and Garston Iron and Steel Company, Limited*	35
		Total	336

* Have six double puddling furnaces on Siemens's plan, reckoned twelve in return. The Ince Hall Rolling Mills Company are erecting six puddling furnaces.

NORTH WALES.

Ruabon ...	Broughton Hall	Broughton Iron Company	10
,, ...	Llay ...	Standing	6
,, ...	Ruabon ...	New British Iron Company	38
Wrexham ...	Stantsy Forge...	Stansty Forge Company	6
		Total	60

SOUTH WALES AND MONMOUTHSHIRE.

Llanelly ...	Amman ..	Amman Iron Company	7
Cardiff	Aberdare&Abernant	Fothergill and Hankey	69
,, ...	Aberamman ...	Standing	17
,,	Pentyrch & Merlin Griffith	T. W. Booker and Company	11
,, ...	Pennydarren ..	Fothergill and Company	—
,, ...	Taff Vale ...	Standing	14
,, ...	Treforest ...	J. Evans and Company	—

Place.	Name of Works.	Owners.	No. of Puddling Furnaces.
Briton Ferry	... Briton Ferry ...	Townshend Wood, and Company ...	42
Abergavenny	... New Clydach ...	Basil Jayne	10
Port Talbot	...Cwm Avon and Taibach ...	Governor and Company of Copper Mines	55
Bridgend	... Llynvi Vale ...	Llynvi Vale Iron Company	32
Merthyr Tydvil	...Cyfarthfa and Ynisfach ...	Robert T. Crawshay	74
,,	... Dowlais... ...	Dowlais Iron Company	160
,,	... Gadlys	Gadlys Iron Company	23
,,	... Plymouth ...	Fothergill and Hankey	68
Tondu	... Tondu ...	John Brogden and Sons	23
Swansea	... Ystalyfera ...	Budd and Company	32
Newport	... Llanelly ...	Standing	10
,,	... Nantyglo ...	Sir J. and C. Bailey	60
,,	... Abersychan ...	Ebbw Vale Iron Company, Limited ...	56
,,	... Victoria ...	Do. Do. ...	165
,,	... Ebbw Vale		
,,	... Pontypool	Do. Do. ...	16
,,	... Blaina ...	Blaina Coal and Iron Company	82
,,	... Cwm Celyn		
,,	... Coalbrookdale		
,,	... Blaenavon ...	Blaenavon Iron Company	63
,,	... Pontnewynydd ...	Standing	—
,,	Varteg and Golynos	Partridge and Jones	23
,,	... Rhymney ...	Rhymney Iron Company	91
,,	... Tredegar ...	Tredegar Iron Company	79
,,	... Oakfields ...	J. C. Hill and Company	17
,,	... Cwm Bran ...	Patent Nut and Bolt Company	20
Aberdare	... Hirwain ...	Standing	19
		Total	1,338

SCOTLAND.

Glasgow	... Blochairn ...	Hannay and Sons	96
,,	... Glasgow ...	Glasgow Iron Company	37
,,	... St. Rollox ...	Do.	13
,,	... Govan ...	William Dixon	40
,,	... Muirkirk ...	William Baird and Company	12
,,	... Parkhead ...	W. and J. Beardmore	28
Coatbridge	... Rochsolloch ...	Rochsolloch Iron Company	12
,,	... Clifton ...	Gray and Wyllie	18
,,	... Coates ...	Thomas Jackson	27
,,	... Wishaw ...	John Williams and Company	11
,,	... Drumpeller ...	Henderson and Dimmack	16
,,	... North British ...	Thomas Ellis	12
,,	... Phœnix ...	John Spencer	23
,,	... Globe ...	A. and T. Miller	5
,,	Coatbridge Tinplate	Coatbridge Company	11
,,	... ,, ...	Hugh Martin and Son	6
Airdrie	... Monkland ...	Monkland Iron and Steel Company ...	60

Place.	Name of Works.	Owners.	No. of Puddling Furnaces.
Holytown ...	Mossend ...	Mossend Iron Company	60
,, ...	Clydesdale ...	Clydesdale Iron Company, Limited ...	10
Motherwell ...	Motherwell ...	Glasgow Iron Company	52
,,	—	David Colville	16
			565

ABSTRACT.

	No. of Puddling Furnaces.
North of England	1,990
North-West of England	75
Yorkshire—West Riding	305
,, South	349
Derbyshire	130
South Staffordshire	2,049
North Staffordshire	444
Shropshire	206
Lancashire	336
Somersetshire	9
North Wales	60
South Wales and Monmouth	1,338
Scotland	565
Total	7,856

LIST OF BESSEMER CONVERTERS.

Sheffield	Jno. Brown & Company, Limited, Atlas Works, two fifteen-ton vessels, two ten tons do., and two 7½ tons do.
,, ...	Charles Cammell and Company, four five-ton converters.
Penistone	ditto four five-ton vessels.
Deepcar	Samuel Fox and Company, two five-ton vessels.
Sheffield	Henry Bessemer and Company, two 3½-ton vessels, one one-ton do., and two five-ton do.
Wednesbury	Patent Shaft and Axle Company, two 3½-ton vessels.
Bolton	Bolton Iron and Steel Company, four five-ton vessels.
Manchester	Railway Steel and Plant Company, four three-ton vessels.
Gorton, Manchester...	Bolckow, Vaughan, and Company, Limited, two five-ton vessels.
Manchester	Sir Joseph Whitworth, one four-ton vessel.
Liverpool	Mersey Steel and Iron Company, four five-ton vessels.
Crewe	London and North-Western Railway Company, four five-ton vessels.
Barrow	Barrow Hematite Steel Company, six five-ton vessels, and twelve seven-ton ditto.
Merthyr Tydvil.........	Dowlais Iron Company, six five-ton vessels.
Ebbw Vale	Ebbw Vale Iron Company, six five-ton vessels.
Ferryhill	Weardale Iron and Steel Company, four three-ton vessels.
Glasgow	Rowan and Company, two three-ton vessels.
The Ickles, Manchester	Messrs. Hampton, Radcliffe, and Co., two five-ton vessels.
Attercliffe, Sheffield.	Messrs. Brown, Bailey, and Dixon, two five-ton vessels.
East Greenwich........	The Bessemer Steel and Ordnance Co., two four-ton vessels.
Rotherham	Owen's Patent Wheel Tyre, and Axle Company, two five-ton vessels.

LIST OF DONATIONS TO THE INSTITUTE SINCE ITS ESTABLISHMENT.

1869. CARDIFF NATURALISTS' SOCIETY—Report and Transactions for 1868 and 1869.

INSTITUTION OF CIVIL ENGINEERS—Gaudard on the Strength and Resistance of Materials ; Ellacot on the Water Basin at Birkenhead ; Grantham on Ocean Steam Navigation ; Dobson on the Public Works at Canterbury, New Zealand ; Harrison on the Statistics of Railway Income and Expenditure.

ROYAL SOCIETY—Proceedings, Nos. 114, 115, and 116.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS, Newcastle-on-Tyne—Transactions.

1870. ROYAL SOCIETY—Proceedings, Nos. 117, 118, 119, 120, 121, 122, 123, 124, 125.

CLEVELAND INSTITUTION OF ENGINEERS—Proceedings at the various meetings.

INSTITUTION OF ENGINEERS IN SCOTLAND—Transactions.

CIVIL ENGINEERS—Terry on the Mhow-ke-Mullee Viaduct ; Stoney on the Pennair Bridge ; Douglas on the Wolf Rock Lighthouse ; Fox on the San Paulo Railway, Brazil ; Sopwith on the Dressing of Lead Ores ; R. Price Williams on the Maintenance of Railway Rolling Stock ; Berkley on the Strength of Iron and Steel ; Cowper on Regenerative Hot Blast Stoves for Blast Furnaces ; Briggs on Rotary Fans ; Fowler and Bainbridge on Coal Mining ; Proceedings, 1869-70, Vols. XXIX. and XXX. (bound); Engineering Institution.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND—Transactions of meetings held session 1870-71.

Mr. D. FORBES, F.R.S.—Structure of Rock Masses, by the Donor.

INSTITUTION OF MECHANICAL ENGINEERS—Proceedings, April 28th, 1870 ; August 2 and 3, 1870, Parts I. and II. ; and November.

SOUTH WALES INSTITUTE OF ENGINEERS—Proceedings, May, September, and December, 1870.

SOUTH MIDLAND INSTITUTE OF MINING ENGINEERS—Transactions, June, 1870.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS—Transactions.

Mr. C. WILKINS—History of Merthyr Tydvil.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS—Proceedings at meetings.

1871. Institution of Engineers and Shipbuilders in Scotland—Transactions, Meetings held Session 1870-71.

Institution of Mechanical Engineers—Proceedings, Jan. 26th, April 27th, July 25th and 26th, and October 26th.

Royal Society—Proceedings, Nos. 126, 127, 128, 129, 130.

Institution of Civil Engineers—Reilly on Studies of Iron Girder Bridges; Proceedings 1868-69, Vol. XXVIII.; On the Archimedean Screw for Lifting Water; on the Treatment of Town Sewage; on the Screw Propeller; on the Clevedon Pier, New Ross Bridge, and Cambrian Railway Viaducts; on the Strength of Cement; on the Pola Dock, Basin, and Railways; on the Water Supply of Paisley; on Phonic Coast Coast Signals; on Floating Docks; on the Testing of Rails; on Metal and Timber Arches; A Description of Two Blast Furnaces at Newport, Middlesbrough; on the Thames Embankment and Coffer Dams; on the Strength of Lock Gates.

Institution of Naval Architects—Vols. I. to XI. of the Proceedings from 1860-70.

The Admiralty—Experiments on Steel and Iron.

Cleveland Institution of Engineers—Proceedings, January, February, March, April, November, and December, 1871.

South Wales Institute of Engineers—Proceedings at various meetings.

Midland Steam Boiler Inspection Company—Report 1870.

London Association of Foremen Engineers—Journal, October, March, April, May, June, July, August, 1871.

North of England Institution of Mining Engineers—Transactions, March and April, 1871.

South Staffordshire and East Worcestershire Institute of Mining Engineers—Transactions, May, 1871.

Commissioners of Patents—Descriptive Indices of Patents applied for and granted during the Quarter ended March 31st, 1867, June 30th, 1867, Sept. 30th, 1867, Dec. 31st, 1867, March 31st, 1868, June 30th, 1868, Sept. 30th, 1868, Dec. 31st, 1868, March 31st, 1869, June 30th, 1869, Sept. 30th, 1869, Dec. 31st 1869, March 31st, 1870; Abridgments of Specifications relating to Weaving, 1620-1859, 1860-1866; Bleaching, &c., 1617-1857; Printing, 1617-1857; Metals and Alloys, except Iron and Steel, 1681-1859; Shipbuilding, &c., 1618-1860, 1860-1866; India Rubber, 1627-1857; Gas, 1681-1858; Electricity and Magnetism, 1766-1857, 1858-1866; Hydraulics, 1617-1865; Acids, Alkalis, &c., 1622-1866; Raising, Lowering, and Weighing, 1865, 1866; Lace, &c., Firearms, 1857, 1858-1866; Spinning, 1864-1866; Railway Signal, 1840-1866; Books, &c., 1768-1866; Tobacco, 1721-1866; Paper, &c., 1858; Part II.; Photography, 1861, 1865; Pottery 1861, 1866; Plating Metals with Metals, 1861; Iron and Steel, 1621-1857; Steam Culture, 1857; Bricks and Tiles, 1862; Roads and Ways; Bridges and Viaducts, 1866; Writing Instruments, &c., 1866; Saddlery, 1866; Watches, Clocks, &c., 1857; Aid to Locomotion, 1857; Drain Tiles and Pipes, 1857; Aeronautics, 1866; Preservation of Food, 1866, 1856; Furniture and Upholstery, 1866; Marine Propulsion, 1857; Manure, 1856.

Cleveland Institution of Engineers—Proceedings, January, February, March, April, 1872.

Institution of Civil Engineers—Address of President (Thomas Hawksley); Annual Report of Council; on the Testing of Rails.

London Association of Foremen Engineers—Journals, Nos. 8, 9, 10, 11, 12, 13, 14, 15, 16.

1872 Royal Society—Proceedings, Nos. 131, 132, and 133.

North of England Institute of Mining and Mechanical Engineers —September, October, and December, 1871, and February and March, 1872.

Manchester Literary and Philosophical Society—Transactions, Vols X. and XI., in numbers.

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Institution of Mechanical Engineers—Proceedings, 25th Jan., 1872.

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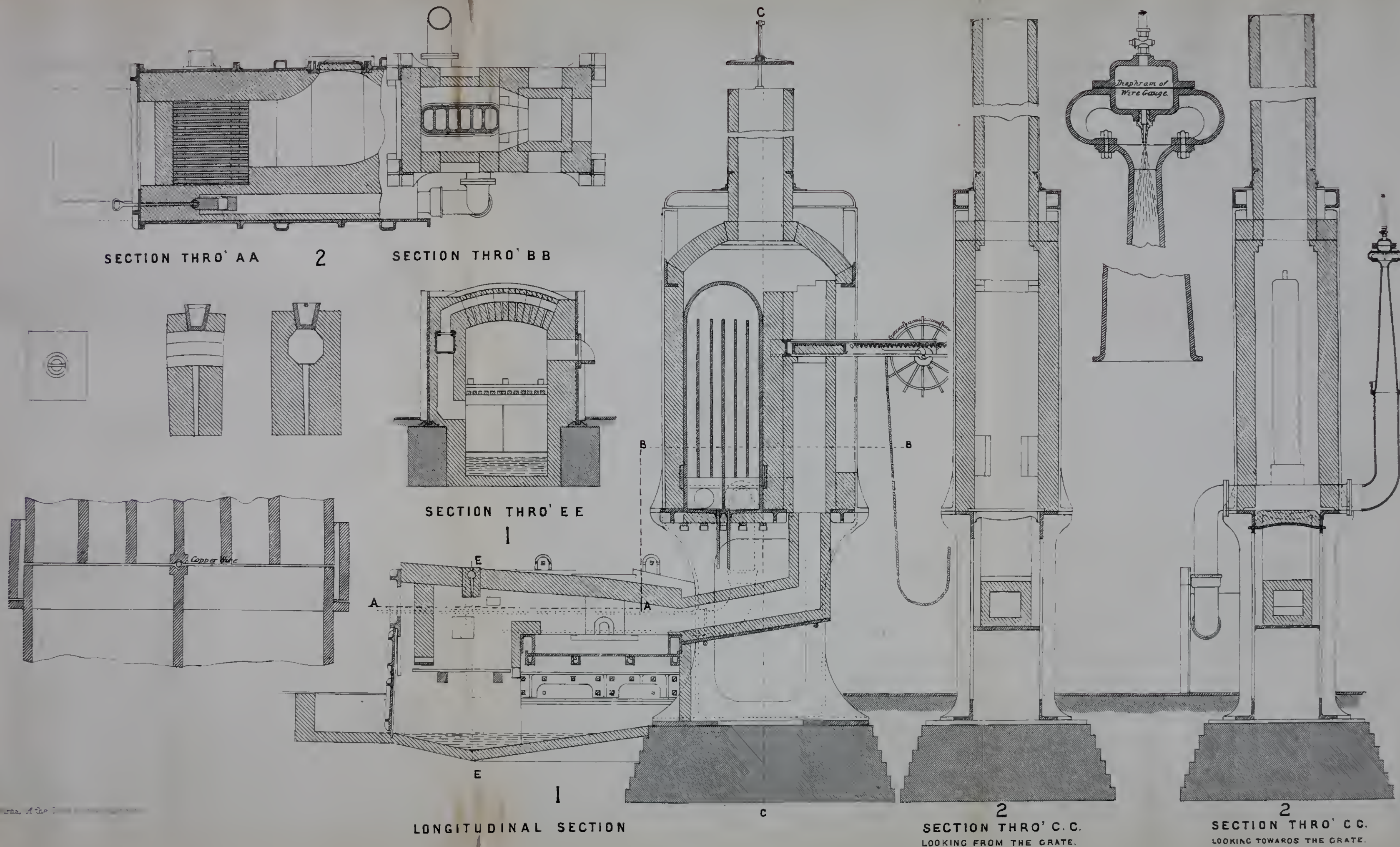
Midland Steam Boiler Inspection Company—Chief Engineer's Report, 1871.

Boiler Inspection Company—Chief Engineer's Report, 1871.

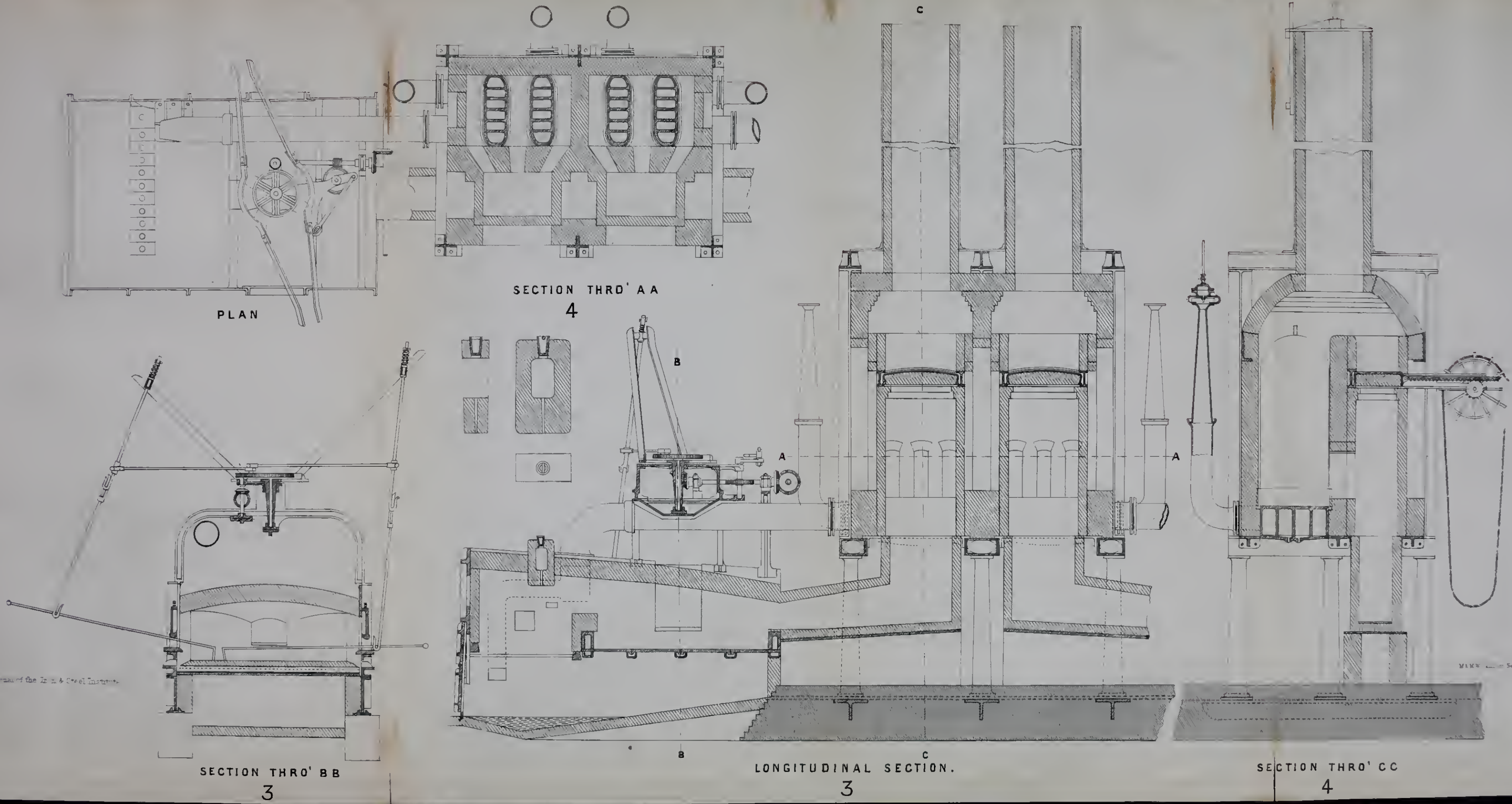
Manchester Steam Users' Association—Chief Engineer's Report, 1872.

☞ Any of the above will be forwarded for perusal to Members on their making application to the General Secretary, Royal Exchange, Middlesbrough.

THE NEWPORT FURNACE.



THE NEWPORT PRINCIPLE ADAPTED TO WHITHAM'S DOUBLE FURNACE WITH MACHINE.



ROTARY PUDDLING FURNACE OF MESS^RS. HOWSON AND THOMAS.

Fig: 1.

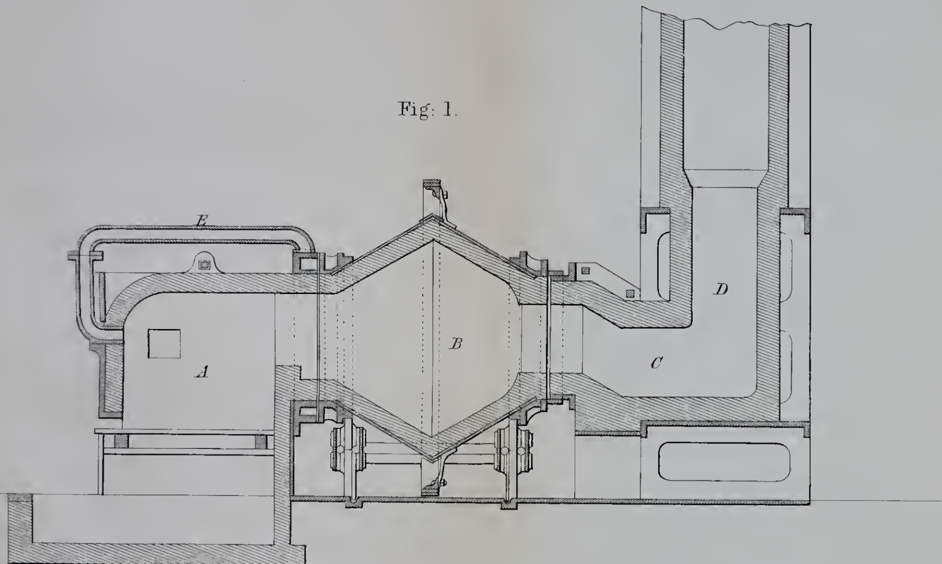
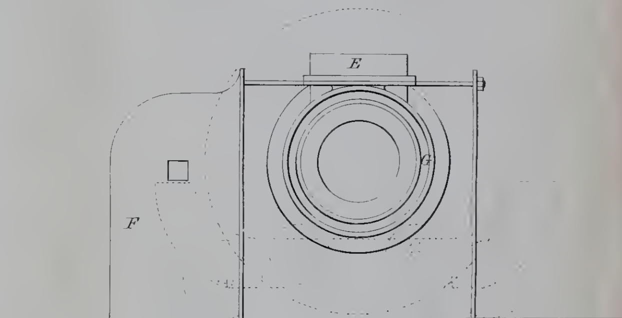


Fig. 2

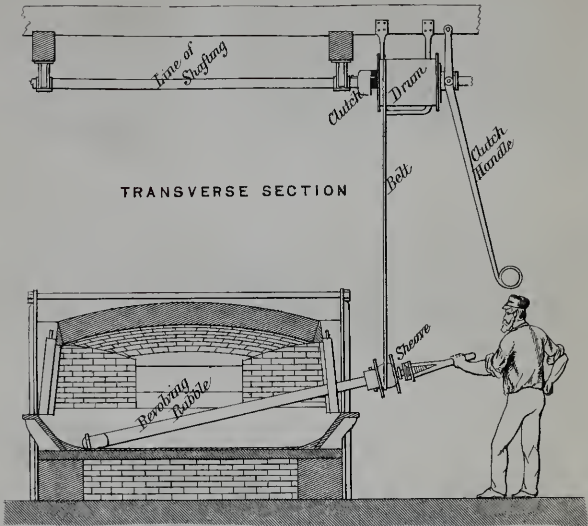


... the Iron & Steel Institute

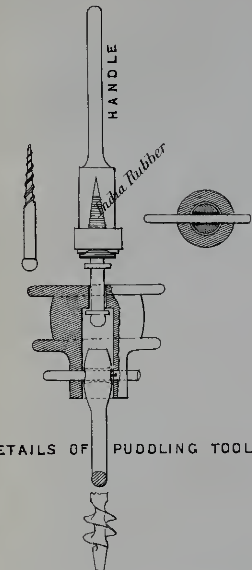
M... W. ... New...

DORMOY'S ROTARY PUDDLING RABBLE;

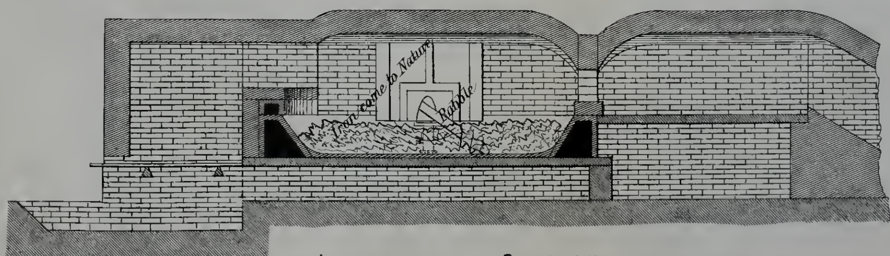
APPLIED TO AN ORDINARY FURNACE.



TRANSVERSE SECTION



DETAILS OF PUDDLING TOOL



LONGITUDINAL SECTION.

M & M W Lambert Newcastle

CHEMICAL PHENOMENA OF IRON SMELTING:

An Experimental and Practical Examination of the circumstances which determine the Capacity of the Blast Furnace, the Temperature of the Air, and the Proper Condition of the Materials to be operated upon.

By I. LOWTHIAN BELL.

(Continued from page 354, vol. II.)

SECTION XXXIX.—ON THE THEORY OF THE HOT BLAST.

In the year 1828, J.B. Neilson patented an "improved application of air to produce heat in fires, forges, and furnaces, where bellows or other blowing apparatus are required." This discovery consisted, as is well known, in heating the air before it is propelled into the furnace; and although, from the title of the patent, Neilson and his colleagues appear to have expected to see it generally employed in all furnaces driven by compressed air, its use has, practically, been exclusively confined to those employed in smelting the ores of iron.

In 1834, Monsieur Dufrenoy was sent over to this country, by the Director-General of Mines of France, to report to the authorities at Paris, on an invention, which at the time was truly described as one revolutionising, in Scotland at all events, where it was first put into practice, the art of making iron.

This gentleman in a report* gave good reasons apparently for this statement, by quoting the experience of the owners of the Clyde Iron Works, which was as follows:—

For the year	1829.	1831.	1833.
Temp. of blast	Cold.	450° F.	612° F.
Coal used per ton of iron	As coke.	As coke.	In raw state.
For fusion, cwts. ...	133	86	40
„ heating air, raw coal	nil.	5	8
„ blowing engines „	20	7	11
	153	98	59
Cwts. limestone per ton of iron	$10\frac{1}{2}$	9	7

* "On the use of hot air in the ironworks of England and Scotland;" translated 1836. London: J. Murray, Albemarle Street.

From this it would appear that heating the air with 5 cwts. of coal had saved 47 cwts. of fuel in the furnace, and 8 cwts. similarly applied had been followed with an economy of 93 cwts., or above 69 per cent.

Besides this advantage, the make was increased by more than one-third, and a blowing engine, which only supplied three furnaces with cold blast, was equal to four when the air was heated.

The iron trade hesitated somewhat in crediting that the heat generated from 8 cwts. of fuel burnt outside the furnace should be able to perform the duty of a very much larger weight burnt inside. Some writers on the metallurgy of iron, when speaking of the advantages of Neilson's system, have perhaps not been sufficiently careful in drawing a distinction between the saving directly due to its application and that arising in a collateral manner from its use. Looking at the question, however, in its commercial sense, the figures and language quoted from the work of Dufrenoy justified the character he gave of it.

There is undoubtedly, as this writer alleged, a saving, and, in the case of the Scotch furnaces, a very great saving, of fuel by the use of the hot blast, exceeding considerably that of the weight of coal expended in the hot-air apparatus; but it seems a mere waste of time to endeavour to assign a cause, *in a heat-producing point of view*, why with the blast at 450°F., obtained by burning 5 cwts. of coal, 93 cwts. of fuel should do the work of 153 cwts. with cold air, for the simple reason that it is incorrect so to state the economy effected by the invention. Thus, the burning of 7 cwts. instead of 20 cwts. of coal, per ton of iron, under the blast engine boilers, does not affect beneficially the quantity, nor the application, of the heat developed in the furnace itself.

Again, according to Dufrenoy, the coal used at the Clyde Works contains 64·4 per cent. of coke; but in the statements of the consumption he gives, there was used, per ton of metal, at the furnace blown with—

					Raw coal.
Cold blast, ...	60	cwts. of coke, obtained from			133 cwts.
Hot blast, 450°F.	38	" " "			96 "
Difference	22	" "		Difference	37 "

These quantities of coke, viz., 60 and 38 cwts., in reality only represent 93 and 58 cwts. respectively of raw coal, the difference between these numbers and those quoted above being waste of fixed carbon in the coking process. Hence, although it may be perfectly correct, commercially speaking, to say there is a gain of 37 cwts. of coal, in a heat-producing point of view, it is only 22 cwts. of coke we have to set against 5 cwts. of coal burnt in the hot-air stoves. This margin of 17 cwts. (the difference between 22 and 5 cwts.), however, is sufficiently remarkable, and various explanations have been given to account for the apparent anomaly. Some of these I propose to examine in the present section, and then to consider the question with the assistance of the experiments and reasoning made use of in my own investigations on the action of the blast furnace.

The late Dr. W. Allen Miller* conceived the economy effected by the use of the hot blast to be due to the reduction of the ore taking place nearer the crucible, and thus concentrating the heat.

The analyses of the gases at different depths of the furnace, quoted in these pages, when blown with cold air, and with that varying from 180°C. to near 500°C., do not appear to afford any countenance to the opinion advanced by this chemist.

Dr. Clark, Professor of Chemistry in Aberdeen, examined, in 1834, the action of the hot blast, and assigned as the cause of the saving of fuel that an ordinary furnace received six tons of cold air per hour, which he regarded as a tremendous refrigeratory passing through its hottest part, and thus repressing the temperature required for the complete and rapid reduction of the iron.

This explanation of the cooling effect of the air is true enough, but it scarcely accounts for the fact that one unit of heat in the blast was at that time saving something like four derived from the fuel burnt in the furnace. Dr. Clark, too, appears to have entertained the same opinion as that expressed some thirty years afterwards by Dr. Miller, viz., that the reduction of the iron was an operation performed in the hottest part of the furnace, whereas it would seem, from the analyses given in a previous part of this work, it is one almost exclusively effected in the coolest region.

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* "Elements of Chemistry."

Mr. Truran, in his work,* maintained that all writers previous to his time had greatly exaggerated the effects of the hot blast in the manufacture of iron. Dr. Percy† has effectually disposed of the chemical reasoning upon which this author supported his assertion. I am not aware that any one pretended that its introduction into Wales had been attended with the same beneficial results which distinguished its use in Scotland, and Mr. Truran certainly did not succeed in proving that Neilson had not, by his invention, afforded very valuable assistance in smelting the black band of that country.

Sir Wm. Fairbairn, in his work on the manufacture of iron, suggests the propriety of investigating the alleged consumption of fuel in the throat of the furnace, to which Mr. Truran attributed certain effects of the hot blast. Sir William himself seems to be under the impression that narrowing the throat increases the effect of the blast in this region. As no portion of the blast ever reaches beyond a few inches from the tuyeres in the form of atmospheric air, whether it is employed hot or cold, and whatever be the shape of the furnace, this view of a change in the nature of the combustion seems also devoid of any foundation.

Dr. Percy, who has examined with great care and minuteness the writings of almost every author, English and foreign, on this question, states‡ that, "after the positive, oft-repeated, and generally credited statements which have been put forth concerning the extraordinary effect of the hot blast in diminishing the consumption of fuel in the smelting of iron, it might seem superfluous to raise any question as to the fact."

The extraordinary effect alluded to by this author would appear to have more special reference to such savings as are contained in the published accounts of the late David Mushet, who gives 148 cwts. of coal coked for making a ton of iron with cold air, against $43\frac{1}{2}$ cwts., used raw, with hot air, at the Clyde Works.

Dr. Percy considers that the abstraction of heat by the expansion of so much cold air when it enters the tuyeres must, by the mere act of dilatation, produce an unfavourable effect on the condition of the furnace, and that heated oxygen, combining more rapidly

* "Iron Manufactures of Great Britain," 1855.
† "Metallurgy of Iron and Steel."
‡ "Metallurgy of Iron and Steel," p. 418.

with incandescent carbon, will give a temperature of greater intensity in the direct ratio of rapidity of combustion. This being so, he adopts, for the sake of argument, the supposition that a metal requiring 1,000°C. for its fusion, might be subjected to a temperature of 999°C. for ever without melting. So it may be, the Doctor continues, in the blast furnace, with respect to the carburization of the reduced iron, and certain other accompanying chemical actions, which may take place with slowness at one temperature, and with rapidity at another, slightly elevated. In order to produce these actions in a furnace on cold blast, it is requisite to consume a much larger quantity of coal than in a furnace on hot blast. A few degrees of temperature may make all the difference. As a further proof that it is *calorific intensity* which constitutes the superiority of the hot over the cold blast furnace, Dr. Percy mentions that in both cases the fuel is wholly consumed, and as the gas also which escapes from the furnace mouth has substantially the same composition, it follows that the *amount* of heat generated in a furnace working with cold blast is enormously greater for a given weight of pig iron than in one working with hot blast, the conditions with respect to quality of ore and fuel, dimensions of the furnace, &c., being supposed to be the same in both cases.

A word or two with regard to the absorption of heat by expansion as the blast enters the furnace, and the identity of the composition of gases from hot and cold blast furnaces.

Admitting that a current of cold air absorbs more heat by its expansion than one of hot air, both having the same pressure, will this absorption, whatever it may be, not be met by the addition of precisely the same quantity of heat if communicated to the blast itself? If so, we are not called upon to explain, so far as this item is concerned, any discrepancy between the heat communicated to the air, and the actual effect it produces in the furnace; for there would be no difference between the two. As regards the composition of the gases, it is difficult to determine, from mere reasoning, what this would be. The action of the blast on the fuel would undoubtedly, in both cases, give CO; and the actual quantity of CO_2 produced by reduction and carbon impregnation would be the same in the hot as in the cold blast furnaces, but what proportion of this CO_2 might suffer reduction to the state of CO is not so clear, but supposing it also were the same in both

furnaces, inasmuch as the cold blast furnace is burning much more C to the condition of CO, and cannot convert more of this CO to CO_2 than happens when heated air is used, it follows that it is highly improbable that Dr. Percy's prediction as to their identity of composition would be realised.

Dufrenoy gives it as his opinion that the virtue of the hot blast is to be ascribed to the higher temperature of the furnace, and in support of this hypothesis, he adduces the fact that less limestone is used than when working with cold air, and hence "this diminution of the fluxing matter is the strongest proof that can be given of the temperature of the furnace. It proves that the earthy particles undergo a degree of heat powerful enough to fuse them, with the addition of a smaller quantity of flux."

This view of the condition of the zone of fusion is also that entertained by Dr. Percy, who reminds us that in looking into the tuyere of a cold blast furnace, the interior is black, instead of presenting the dazzling bright appearance of one blown with heated air.

As regards the diminution of limestone, there are other objects to be gained than the mere fluxing of the earthy constituents of the ironstone, such as the removal of sulphur, &c. This would appear to be so, because it often happens that the earths, in the proportions in which they exist naturally in an ore, constitute a readily fusible slag without the addition of any flux; thus, according to Colquhoun, in Scotch Black Band, we have them as follows:—

$$Si\,O_2\ 38,\ Al_2\,O_3\ 21,\ Mg\ O\ 18,\ Ca\ O\ 23{=}100.$$

Exp. 743. A mixture of these four substances in the specified quantities was exposed to the heat of a smith's forge, when it melted readily into a vitreous slag; and similarly, when they were in the proportions in which they are found associated in the Cleveland ironstone, they afforded a beautiful white glass.

The supposed duty of lime in removing sulphur, and it may be phosphorus to some slight extent, often leads to its use where the quantity, instead of adding to the fusibility of the slag, has a precisely opposite effect. Such, at least, is apparently the case in smelting the ironstone of Cleveland, judging from the slag formed upon one occasion when, by way of experiment, all limestone was withdrawn from the charges. The slag was well fused, but the iron

became hard, and contained above three times the usual content of sulphur.

The darkened appearance of the hearth, spoken of by Dr. Percy,* is susceptible of another explanation than that of an actual general refrigeration of this region. It is more probable, it occurs to me, that the cold air meeting the slag and iron, chills a small portion of the fused matter as it passes the tuyeres, but this, of course, is not the action of air on carbon, but of air upon slag and metal. When, on the other hand, the melted contents of the furnace trickle down before a current of heated air, they also, no doubt, are chilled, but not to the extent to deprive them of fluidity before they pass beyond its influence, and, in this way, there is no accumulation of solidified matter, which gives rise to the prolonged tube or "nose," as it is termed, reaching far into the hearth.

To account for this supposed increase of intensity in the heat of a hot-blast furnace, Dr. Percy quotes the experiment of the Swedish metallurgist, Mr. Sandberg, who observed that heated oxygen combines more rapidly with incandescent carbon than cold oxygen, and that in consequence there "must be a proportionate increase of temperature, for *cœteris paribus*, temperature will be in the direct ratio of rapidity of combustion."

Ordinary combustion of carbon is generally spoken of as an oxidizing of the carbon about to be burnt, and this no doubt, looking at the office played by oxygen in combustion generally, is a convenient mode of expressing the action. But as combustion of carbon is no more the oxidation of this element than it is the carburizing of oxygen, it will be more convenient, for our purpose, to speak of it in this inverted manner. Now, when oxygen is propelled into *a blast furnace*, it becomes rapidly carburized to its utmost limit of saturation, *i.e.*, it is speedily converted into CO. This union with carbon is so instantaneous that free O is never mentioned as the constituent of any analyses of furnace gases I have met with or made. Hence if there was any difference in the extent to which the oxygen became carburized as between cold and hot blast, it would manifest itself in the larger quantity of CO_2, where the rapidity of combustion was the least, because in this case the oxygen is unable to take

* "Metallurgy of Iron and Steel," p. 427.

up as much C as when the union is more speedy, and this slowness of combustion is what Dr. Percy concludes will happen when the oxygen is driven into the furnace as cold blast.

Were it consistent with observation that this carburization of oxygen were retarded by the want of heat in the oxygen, I would submit that the very opposite effect to that mentioned by this writer would ensue at the tuyeres, *i.e.*, instead of a cold blast furnace having a lower temperature generated in the hearth, it would be much hotter, inasmuch as the heat evolved by carburizing O to the lower state of CO_2 is three times that produced by the more perfect carburizing of the blast, which happens when CO is the product.

We need only refer to what has been said in Section XXX. on the origin of the heat in the blast furnace to be satisfied that no temperature to which it would be possible to raise the air could compensate for such a difference as exists between carburizing O to the condition of CO_2 and CO, 8,000 calories being the product of one unit of carbon passing to CO_2 against 2,400 when the other oxide is produced.

The following analyses, given in Dr. Percy's work, show the volumes of CO and CO_2 per 100 volumes of the gases:—

Furnace.	Blast.	Gases collected at	CO.	CO_2
Clerval—cold	...	... Tymp ...	39·86 ...	·93
Do.	190°C. (374°F.)...	18in. above tuyeres	41·59 ...	·31
Eisenerz,	200°C. (392°F.)	Level of tuyeres	22·06 ...	11·60

Is there, however, any valid ground for asserting that the carburizing of the injected oxygen is slower when it is cold than when hot? In the analysis, referred to by Dr. Percy himself, of the gas taken from the tymp (about the level of the tuyeres) of the Clerval furnace blown with cold air, there are 39·86 vols. CO to ·93 vols. CO_2. At the same place, when the blast was used at 190°C. (374°F.), a specimen of gas 18 inches above the tuyere, and therefore vertically about as far from the point of entrance of the O as the other was horizontally, 41·59 vols. of CO were accompanied by ·31 vols. of CO_2. This difference, small as it is, must be regarded rather as accidental than general, and, under no circumstances, can account for any great change in the actual temperature.

The information, however, elicited by an analysis of the Wear gases, taken from the level of the tuyeres, shows that carburization

of the oxygen is not more rapid with the blast at 460°C. (860°F.) than it was at Clerval with cold air.

	CO.	CO_2.
Exp. 744.	37·5	·76
„ 745.	37·7	·76
„ 746.	35·8	2·10
„ 747.	31·7	1·1
„ 748.	33·8	·8

All this argument, nevertheless, would have to give way to the fact, could it be established, that the temperature of the hearth of a hot-blast furnace really did exceed that of one blown with cold air.

I have already (Section XXXVI.) alluded to the difficulty experienced in obtaining, by means of the calorimeter, any data sufficiently uniform to enable me to determine the temperature of the contents of the hearth of a furnace. In the same place, however, I have given my reasons for believing that the cause of the difference between white iron and grey was simply one of temperature. This was done, it may be recollected, by heating white iron to a point known to be sufficient to produce grey iron, and the change was effected, *i.e.*, the white became converted to grey. The plan followed consisted in plunging a bar of white iron in a current of slag, as it issued from a furnace producing iron grey in quality.

Since writing the account of this experiment I have, by the kind assistance of my friends, the Messrs. Kitson, of the Monkbridge Works, at Leeds, satisfied myself of its correctness by another mode of procedure.

Exp. 749. About 60 lbs. of Clarence white pig iron was melted in one of their Siemens steel melting furnaces, and run into a mould of green sand forming a cube of 6 inches on a side. With the exception of a trace of white at one corner, the whole was converted into uniform good grey forge.

Exp. 750. The same quantity of the same iron as that used in the previous experiment was melted on a Saturday, and allowed to remain over the Sunday in the furnace, during which time it cooled slowly. The block, having a maximum diameter of 6 or 7 inches, was entirely grey, chiefly No. 3, interspersed with some No. 4.

It seems, therefore, not unreasonable to accept the iron made in any particular furnace as a species of pyrometer for determining, if not the actual temperature of its interior, at all events of establishing a comparative test between it and that of another.

If then, temperature is the governing cause of quality of iron (numbers), it is highly improbable that the same degree of heat intensity is *cæteris paribus* making white iron in one furnace and grey iron in another. It does seem more rational to suppose that if two furnaces are both running, say No. 3 iron, from the same materials, one blown with hot air and the other with cold, they are making the same quality, because the temperature is the same in both.

This admission as to parity of temperature, of course, does not presuppose that the heat evolved by the combustion of carbon with hot air is not more intense than that arising from cold air; but what I affirm is that, in consequence of the greater amount of iron and slag being melted with a given weight of fuel, when burnt with hot blast, the actual temperature in the crucible of such a furnace, is probably lowered to that of one blown with cold air, having a smaller weight of material to fuse.

In recent years, by raising the temperature of the blast to 485°C., the consumption of coke has been reduced to 28 cwts. per ton of iron when smelting Cleveland ironstone in a furnace 48 feet high, and in which probably more than 60 cwts. (the quantity named in connection with the Scotch furnaces) would at least be required with cold air. Of the carbon in the 28 cwts. of coke mentioned above, after deducting that dissolved by the CO_2 of the flux, about 25 cwts. would be burnt to CO at the tuyeres.

25 cwts. C × 2,400	... =	60,000 calories.
Blast will contain about	... ...	16,000 „
		76,000 „

The intensity, however, of this quantity of heat has been shown in Section XXXVII. to be greatly augmented by that intercepted by the materials and brought down again to the zone of fusion. This was in one case proved to amount to 70 per cent. of that actually evolved by the quantity of fuel consumed to produce one ton of iron. So far as intensity therefore is concerned, we have to deal with

Units from coke per ton of iron	76,000	calories
Plus 70 % intercepted and brought back ...	53,200	„
	129,200	„

In like manner, with a consumption of 60 cwts. of coke, about 54 cwts. of carbon would be burnt at the tuyeres to CO.

54 cwts. C × 2,400 ... =	129,600	calories
Plus heat in blast, about	2,400	„
	132,000	„
To which if we add for intercepted heat 70 per cent.	92,400	„
There is obtained	223,400	„

Now, it seems on the face of it, incredible that the mere addition of 16,000 cwt. heat units, in the place of 2,400, should so alter the intensity of heat in the crucible as to make all the difference in the work performed.

Upon a former occasion* I called attention to the fact that whereas in the hearth of a blast furnace the C was burnt to CO, in the hot-air stoves it left the fireplace as CO_2. This of itself would enable each unit of carbon to give 3·33 times as much heat when burnt in the hot-air apparatus as when burnt in a blast furnace. The advantage, however, resulting from this change in the manner of combustion, would be considerably diminished by the great loss from radiation, and at the chimney of the heating stove. This is conclusively exhibited by the fact that whereas at least 4 cwts. of coal, equal to 32,000 cwt. heat units, are used per ton of iron in the stoves of a 48-feet furnace, only 16,000 find their way through the tuyeres.

Upon the same occasion I alluded to the circumstance that the mere alteration of the proportion of ironstone to coke conferred an advantage upon the hot-blast furnace, by presenting to the ascending gases a greater quantity of matter having a higher heat-absorbing power, ironstone being superior in this respect to coke.

Exp. 751. To determine the relative powers of coke, limestone, and ironstone, a cast-iron cylinder was provided, four feet long and one foot in diameter, closed at each end. The material

* "Chemistry of the Blast Furnace. Transactions Chem. Soc. of London, 1869."

to be operated on, broken as nearly as possible to the same size, was introduced into the cylinder, which it filled, and by means of an inch pipe hot air was introduced at the low end and allowed to escape at the upper. This was continued until a thermometer inserted at the top became stationary.

Numbers of a very constant character were obtained when using the same substance, and from these were deduced that bulk for bulk, taking coke as unity, the intercepting power of

Coke being	...	1·00
Cleveland calcined ironstone was	...	2·00
Limestone „	...	1·60

These figures, however, indicate that the heat-absorbing power of a hot-blast burden is only about 10 per cent. superior to that of cold blast.

Under these circumstances, therefore, it is clear that neither modifications of the circumstances just mentioned, can account for more than a very small proportion of the actual saving effected by the use of heated air.

In the treatise by M. Dufrenoy, pointed allusion is made to a fact in connection with the use of hot air in France when using certain ores, from which it would appear that practically no saving whatever resulted from its application to the smelting of the mineral used at La Guerche,* which, although containing only 42 per cent. of iron, gave a ton with 25 cwts. of fuel and cold air.

Mons. Dufrenoy dismisses, what seems to me a very important matter in connection with the theory of the hot blast, with the simple observation that the figures, in connection with the Guerche furnace he quotes, are "not favourable to the use of hot air," and I am not aware of their having attracted the notice of any subsequent writer on this interesting question.

It may be remarked that the "extraordinary saving" mentioned by most authorities as consequent upon the use of the hot blast seems to have been regarded in the light of one of general application. At all events, little stress has been paid to the well-known

* This furnace was compared, by Dufrenoy, with a neighbouring one at Torteron, using the same kind of fuel and ore, to which heated air was applied. The only change caused by the altered mode of working was, that the iron, instead of being white, as it was when cold air was used, became grey.

fact, that in many instances the economy of fuel was considerably less than in Scotland, where its much greater importance has, so far as I know, formed the usual ground upon which its powers were considered.

Dufrenoy himself, for example, mentions the circumstance that at the Plymouth Iron Works, near Merthyr Tydvil, a ton of iron was produced with 53 cwts. of raw coal, and that by the use of hot air it could be reduced to 36 cwts. The saving, 17 cwts. of Plymouth coal, only represents 13 cwts. of coke, instead of the 22 given as that effected in Scotland by hot air.

Now, the problem I would suggest to those who allege that "calorific intensity in what may be considered the most active part of the furnace is higher in the case of hot blast than in the case of cold blast" is, whence arises it that the addition to this assumed intensity of heat in the crucible is attended with such different results as those just mentioned?

I cannot help thinking that the answer to the above enquiry is to be sought for in an entirely different direction, and, in pursuit of which, may be quoted the results of certain experiments described in the earlier sections of this work. In these it was conclusively proved that differently prepared specimens of oxide of iron and different kinds of ore, all being peroxides, were very differently affected by the application of heated CO. Thus, in about seven hours, at a temperature of 410°C. (770°F.), in

Exp. 30.	Fe_2O_3 from calcined nitrate, lost		72·7	% of its	original O.
„ 29.	„	precipitated	66·7	„	„
„ 28.	„	from calcined $Fe\ SO_4$	61·7	„	„
„ 35.	Lancashire hæmatite		57·4	„	„
„ 34.	Calcined spathose ore		28·4	„	„
„ 33.	„	Cleveland ore	20·7	„	„
„ 26.	„	„	9·4	„	„

Now, the two experiments 33 and 34 may be taken almost as an exact type of what happens in the Plymouth and Scotch furnaces respectively. We have calcined spathose ore losing its oxygen with nearly one-half more rapidity than that of the Cleveland hills. This would mean that for the purpose of complete reduction we should have to expose the last-mentioned mineral for a one-half longer period of time than the other.

Let us see how this difference in susceptibility to reduction

accounts for the greater consumption of fuel in the case of the black band, as compared with the ore smelted at the Plymouth Works, both of which will be regarded as yielding the same per centage of iron.

In the first place, it is obvious that it cannot be from any difference in the cooling effect of expanding air, as the blast is cold in both cases; neither can it be rapidity of combustion causing intensity of heat, because, if both furnaces burnt the same quantity of fuel in a given time, the Scotch ore would still continue to require the larger quantity of combustible per ton of iron.

It can hardly be alleged that the same quantity of iron and slag to be melted, derived from black band, can require for their fusion in the hearth one-half more heat than do the same substances from the mineral operated upon in South Wales.

Instead of all this, let us suppose that in the hearth of a blast furnace a certain mixture of reduced iron and earthy matter had to be fused, with the minimum quantity of fuel capable of evolving, with cold air, the necessary heat. From the combustion is generated a certain quantity of CO, which we will further suppose to be able to carry off all the oxygen contained in the minerals, without difficulty. This carbonic oxide now commences to flow through the oxide of iron at a rate determined by the rapidity of the combustion and fusion at the tuyeres.

Reduction is effected by the current of CO, and in the case of the Plymouth mineral it takes place at such a rate that by the time about 40 cwts. of coked fuel, the produce of 53 cwts. of Welsh coal, are burnt at the tuyeres, deoxidation has been completed, and carbon-impregnated iron is ready for fusion.

If, however, another ore, say black band, parts with its oxygen much more slowly than that just described, it is certain that the exposure to the reducing agent must, by so much, be prolonged. This, however, cannot be accomplished if the rate of fusion continues the same as it was in the Welsh furnace. There is, therefore, no alternative, in a small furnace, but to retard fusion by the addition of fuel. This reduces the weight of material to be melted, and at the same time supplies an *extra* quantity of CO, which also assists in overcoming the want of susceptibility of reduction inherent in the more refractory ore.

The law, therefore, which I believe determines the whole ques-

tion of differences of fuel required to smelt ores of different kinds, but containing the same percentage of metal, and which constitutes the value of the hot blast is—*that the rate of reduction must not proceed less rapidly than that of fusion.*

It must not be imagined that if a sample of the Scotch black band and one from Plymouth were exposed to a current of heated CO, that deoxidation would necessarily take place exactly at the rates indicated by the quantity of coke required respectively to smelt them—at the same time a fair idea would in all probability be obtained by the information afforded by such a trial.

In the hearth of the Scotch furnace there will be evolved for each ton of iron something like 132,000 cwts. heat units, against 88,000 at Plymouth, both being blown with cold air. It will be observed that in both cases the actual quantity of heat is greatly in excess of what can be possibly required for fusion of iron and slag. This excess, after satisfying the requirements of the crucible, is carried off in the gases, a much larger quantity, of course, in that where the consumption of fuel per ton of iron is the largest. The application of the law just laid down to the two examples now considered, consists in supposing that under the circumstances of size of furnace, &c., whereas 60 cwts. of coke was needed in Scotland to bring the reducing and fusing powers in harmony with each other, the coke from 53 cwts. of raw coal (about 40 cwts.) sufficed to effect the same object at Plymouth.

It may not be altogether out of place, before proceeding further with the present argument, to examine a little in detail the performance of the Guerche furnace, which, although of very small dimensions, when using ore of about the same richness as that of Cleveland, and requiring the same quantity of limestone, produced with cold air, a ton of metal for 24·92 cwts. of fuel.

This of course means that, notwithstanding the small capacity, the ore employed surrendered its oxygen so freely that the current of gases proceeding from the above-named quantity of fuel, became saturated with oxygen by the time they reached the throat, and quite as rapidly as the carbon burnt at the tuyeres could fuse the reduced metal and slag.

No account is handed down to us of the composition of these gases; indeed, at the period of M. Dufrenoy's observations, this subject had received but small attention. All we can, therefore,

do is to consider how far the quantity of fuel consumed can be made to correspond with the actual amount of heat required.

The fuel employed consisted of two-thirds charcoal and one-third coke, but as the work done at Guerche was compared with that of another furnace (Torteron), also using the same mixture of combustible, but blown with hot air, and as we are now considering the quantity of heat, which is the same practically from coke and charcoal, the presence of the latter may be disregarded.

Fuel consumed per ton of iron ...		24·92 cwts.		
Ore		48·74		
Limestone		11·16		
Estimate of heat development—				
Fuel burnt	24·92			
Deduct, say 10% for impurity	2·49			
		22·43		
C in limestone carrying off equal weight from fuel ($CO_2 + C = 2\,CO$) ...		1·32		
				units.
C burnt to CO		21·11	× 2,400	= 50,664
C of this CO burnt to CO_2, say ...		6·00	× 5,600	= 33,600
Heat units in blast from compression, say				2,000
				96,264

Heat absorption as per table in Section XXVIII. :—

Evaporation of H_2O in fuel	312	
Reduction of Fe and carbon impregnation...	34,548	
Expulsion of CO_2 from limestone 11·16 × 370...	4,129	
Decomposition of this CO_2 ... 1·32 × 3,200...	4,224	
Do. H_2O in blast	2,720	
P, S, and Si reduced, assumed one-half* ...	2,087	
Fusion of iron and slag	23,100	
Transmission of heat through sides	3,658	
Tuyere water	nil.	
	74,778	
Leaving (which is more than ample for escaping gases)†	11,486	
		96,264

* Probably less P and Si than in Cleveland iron.

† In all probability, 6 of C, burnt to CO_2, is 1 cwt. in excess of actual quantity, which would reduce heat in gases to 5,886 units.

Thus it will be observed that even with cold air, under favourable conditions, a ton of iron can be obtained from an ore of only medium richness with 25 cwts. of fuel.

Suppose now in this Guerche furnace, containing, probably, only 3,000 to 4,000 cubic feet, it were attempted to smelt Cleveland ore, which, so far as yield of iron and consumption of flux are concerned, nearly approaches that affording the results just given.

In order to prolong the contact between the ore of Yorkshire and the reducing gases, as well as to increase the deoxidizing power of the latter, probably not far short of 65 cwts. of fuel would be necessary to obtain a ton of iron. No less than 40 cwts. being thus expended in establishing the proper relations between the co-efficient of fusion and that of reduction.

There is, however, another method in making amends for this want of harmony between the two functions of the blast furnace. Instead of delaying the fusion of solids, and increasing the energy of the reducing gases by the addition of CO, the same object may be attained if contact is prolonged in a furnace of larger capacity.

In illustration of this mode of action, I will again quote from the experience and figures kindly communicated to me by my friend, Mr. Horton, of the Lilleshall Iron Company.

In furnaces having a height of 53 feet, driven with cold air, an ore poorer than the Scotch black band, and containing about 43 per cent. of iron, calcined, was smelted with about 40 cwts. of coke, affording another case of an ironstone more reducible than those which hitherto have formed the favourite basis of estimating the effects of the hot blast.

Here the available heat may be taken at fully 25,000 cwt. units beyond that which could possibly be absorbed in the process, and which, in consequence, must have escaped from the throat.

Mr. Horton, encouraged by the example of the Cleveland ironmasters, proceeded to add to the capacity of his furnaces. Having to deal with materials entirely different in character from those used in the neighbourhood of Middlesbrough, this gentleman deemed it prudent to proceed with caution, and therefore contented himself with raising his furnaces to a height of 71 feet.

The result was most satisfactory, and at Lilleshall may be seen six cold blast furnaces, making good foundry iron with 27 to 28

cwts. of coke, which is fully as small a quantity as would have been required in the old furnaces of 53 feet, had they been blown with an air at 450°C. (842°F.)

Possibly, looking at the tender nature of the coke at Lilleshall, and the size of the ironstone, Mr. Horton may have been quite right in not venturing on the adoption of the dimensions found now so commonly on the banks of the Tees, where the coke is dense and the ore in large pieces. Were it possible, however, to treat the Shropshire minerals in a furnace 80 or 85 feet high, so far as fusion and reduction are concerned, I apprehend there is little doubt the coke consumption might be reduced to that of Guerche, viz., 25 cwts. to the ton of iron, for it is obvious with an escape of 25,000 cwt. units there is still a considerable margin for economizing.

Had such an alteration, as that just described as having been made at Lilleshall, been carried into effect before the introduction of the hot blast, even in the then state of knowledge of the theory of iron smelting, the inference would have been inevitable, that the advantage obtained by raising the furnace was solely due to its imperfect nature—in short, that just as the Stückofen was inferior to the first high blast furnace, so was the furnace of 53 feet at Lilleshall inferior to that of 71 feet.

Like the discovery of Abraham Darby in using mineral fuel for iron smelting, it is impossible to overrate the value of the hot blast at the period of its first introduction. Indeed, I am not prepared to say that for the black band of Scotland, it may not have nearly as great a value still, due to some mechanical difficulties in its treatment, such as forcing the blast through a very high column composed of this mineral and raw coal, and which, therefore, may render a lower furnace necessary, unless when assisted by Mr. Ferrie's coking chambers. In this opinion I am guided by the alleged want of success experienced by the Scotch ironmasters, when they raised their furnaces in former years, and by the opposite results obtained by Mr. Ferrie.

Apart from any such impediments as those just mentioned, what I consider as beyond all doubt is, that the value of the hot blast at the period of its invention was, so far as any "extraordinary effect" is concerned, solely due to the defective nature of the furnaces then in use, and that when this is remedied, 1,000 units

of heat in the blast can be as easily accounted for as a similar quantity derived from the combustion of fuel in the hearth.

We have only to appeal to the knowledge afforded at Lilleshall in verification of this statement. Foundry iron is there produced with cold air by, say, 27½ cwts. of coke. Let 12,000 heat units be thrown in with the blast, which are equivalent to 4 cwts. of coke burnt with air at 485°C. to CO. This at once is a reduction of the fuel consumed to 23½ cwts., which is probably not far off the actual quantity a furnace of 71 feet would require.

Speaking from the accumulated knowledge respecting the action of iron smelting obtained in recent years, we have seen that valuable as the hot blast was when applied to furnaces of moderate height, it was far from remedying entirely the structural defect alluded to above, for it was not until those of the largest description had their capacity doubled, that something like the full economy in smelting the ore of Cleveland was reached.

Returning for a moment to the enlarged Lilleshall furnaces, we have seen that precisely the same object was secured whether, as in their case, an addition to the size was the means employed, or the blast was heated. Exactly the same law holds good with the furnaces of the former moderate dimensions heated with air at 450°C. They may be enlarged, as has been done in most cases in the North of England, or they may be retained of lesser dimensions, and fed with air at 600° to 700°, according to the mode pursued at Consett.

The limit, or what I have already stated, and what, in a future section, I shall again state, I consider to be—the limit of economy—once reached, very large capacity and very highly heated blast simply tend to neutralize each other.

It may be urged that whether a certain number of heat units is communicated to the blast, and, rising upwards, is intercepted and returned downwards, or whether the same result is brought about by an increase of capacity in the furnace, the effect upon the temperature of the crucible will be the same, and that in each case, it may be supposed, the heat of the latter will be augmented.

Not having access to any furnace (close topped) using cold blast as would permit an accurate examination of the actual temperature of the escaping gases, after an addition to its capacity has been made, I have been unable to prove, by actual experiment, what the

effect has been of such increase of size, and of comparing such results with those at furnaces of similar dimensions using hot air, both being engaged in smelting the same kind of ironstone. Under these circumstances, I have been compelled to make use of such data as I possess, which, unfortunately, are not the best fitted for the object in question, because the materials under treatment differed considerably in their nature.

The furnaces selected for the purpose were two at Cyfarthfa, 52 ft. high, one blown with cold air, and the other with its blast at 332°C. (610°F.) The latter, using fully 8 cwts. less fuel per ton of iron than the other, nevertheless, had its gases passing off 60°C. (108°F.) hotter than those of the cold blown furnace.

It was mentioned, in the present section, that waste of fuel in the blast furnace arose from a want of harmony between the operations of fusion and reduction, the latter not keeping pace with the former. I have shown how this was remedied by increasing the opportunity the reducing gases had for acting on the oxide of iron. This was effected by a prolongation of contact, obtained by enlarging the furnaces, but we have only to refer to those experiments which were undertaken for the purpose of ascertaining the laws which regulate the conduct of the substances met with in the process of smelting an ore of iron, to see that the shorter period of contact can be maintained, or even curtailed, provided the energy of the reducing agent is augmented. Thus in Exp. 36, while calcined Cleveland stone lost 37·3 per cent. of its oxygen in eight hours, by being exposed to CO at a temperature of 410°C. (770°F.), the same ore lost (Exp. 49) 63 per cent. at a dull red heat in the same time, and 90 per cent. (Exp. 50) was expelled in $3\frac{3}{4}$ hours, the temperature being that of bright redness.

I infer, therefore, that the improvement by the use of the hot blast, is not due to any additional heat reconveyed to the hearth, but that such heat is utilized in promoting the energy of the reducing gases in the upper zone, and having done this, it is carried off from the outlet of the furnace. The reasons have been mentioned to show it is unlikely that the temperature of the hearth is really sensibly increased, and also that a very small addition to that of the escaping gases greatly augments the power they possess of causing reduction. It seems to me, therefore, much more probable that the advantage derived from the use of

heated air must be ascribed to the increased temperature in the upper region of the furnace, by which the process of reduction is hastened in a corresponding ratio. In this way, although fusion goes on at an increased speed in the hearth of hot-blast furnaces, on account of the decreased quantity of fuel by which it is effected, as reduction experiences a still greater acceleration, the two operations are carried on in harmony, in point of time, with each other.

If then, we take the case of a cold blast furnace of 52 feet, consuming any given quantity of coke per ton of its product, I say that the temperature of the hearth is the same as that of any hot blast furnace producing the same quality of metal, from the same materials, and that the action of reduction being too languid in comparison with the process of fusion, a loss of fuel is the result, in the manner already described, and that this loss may be remedied either by prolonging contact, or by increasing the energy of the reducing gases by communicating heat to the air used for effecting the combustion of the carbon in the hearth. Further, I say that when no such want of harmony between the two branches of the process obtains, as in the case of the furnace at Guerche, no such stimulus as that afforded by the hot blast is required. From this latter statement it must not be concluded that no saving in fuel would accrue to a furnace using 25 cwts. of coke to the ton of iron by the addition of a high temperature to the blast. The calories, however, so contributed would be found to correspond, in all probability, very closely with those afforded by so much coke economized by the change.

I may be excused, if I parenthetically notice the great advantage to be derived from a perfect understanding of the fundamental principles which lie beneath a process so essentially chemical as that carried on in an iron furnace. It seems scarcely possible to imagine that had the ironmaster, before Neilson's time, been aware, and, being aware, had seriously considered, that in many cases, out of 133,000 calories actually evolved, he only beneficially applied 49,000, or about one-third of the whole, we should not have had to wait for the accidental observation of a thoughtful gas works manager, before attempting to avoid part of the loss of 63 per cent. of his fuel, which might have been done by the simpler plan of increasing the size of the furnace, in which, if the remedy be not

perfect, it is at least as much so as that effected by the hot blast itself.

Greatly curtailed in point of importance, as I deem the use of hot air to be, since the adoption of recent improvements, I would not have it supposed that it has to be regarded in any other light than that of a very powerful and valuable aid to the iron smelter. Its mode of application is so direct and simple that heat may be conveyed in greater or less quantity, as may be required, at once to the focus of most intense temperature, without waiting for a change in the materials which requires some time before it reaches the tuyeres. This assistance too is afforded by a fuel, the escaping gases of which, in many cases, if not so applied, would be wasted. These attributes, even in their modified form of usefulness will, in my opinion, ensure for Neilson's discovery a lasting position in the science of iron metallurgy, and will preserve for his name an exalted place among the most illustrious of those who, by their ingenuity, have advanced the industrial resources, and, therefore, the national importance of their country.

SECTION XI.—ON THE EFFECT OF THE HOT BLAST ON THE QUALITY OF THE IRON.

Like many new inventions, the hot blast met with considerable opposition at the period of its introduction. In Scotland, including the coal used at the blowing engine, the waste incurred in coking the coal, and all other items, the reduction in the quantity of fuel often amounted to 75 %. According to M. Dufrenoy, the money value arising from this source, and that derived from a diminution in the general working charges, from the increased make, amounted to £1 5s. 11d. per ton of iron, made with air heated to 322°C. (611°F.)

With the Scotch pig iron makers, this difference in cost bore down all resistance, and every establishment in that part of the kingdom

was speedily blown with hot blast. Wales, up to the period of Neilson's discovery, was, according to Dufrenoy, able to produce pig iron at a lower rate than any other locality in Great Britain. Unfortunately for the Principality, the mere act of heating the air completely changed the aspect of affairs, for while this modification of the manufacture was followed by a saving of 26s. per ton in Scotland, something like 1s. 8d. was all the benefit its adoption was, according to the French engineer, able to afford to the Welsh ironmaster.

The Glasgow makers enjoyed immense advantages in the possession of their cheap and rich ironstone, but, unfortunately, these were, in a great measure, neutralized by its refractory nature when smelted in small furnaces (50 feet) with cold air, a difficulty which involved the consumption of a large quantity of fuel, raised at a higher price than that of the Welsh coalfield. This objection was remedied by the addition of 600°F. to the blast.

In Wales, on the other hand, the ironstone was poor, but easily smelted; the coal was cheap (3s. 7d. per ton, Dufrenoy states), rich in carbon, so that 50 to 54 cwts. were able to produce a ton of metal. This quantity could only, it was estimated, be reduced 17 cwts. by the use of the hot blast, from which had to be deducted 6 cwts. consumed in the heating apparatus, leaving a net gain of 11 cwts., equal to the saving of 1s. 8d. per ton, of which 1s. had to fall to the share of the patentee.

After some unsuccessful litigation in disputing the legal position of Mr. Neilson, many of the Welsh ironmasters discontinued the practice of heating the blast, it being pretended that the trifling saving in cost was more than swallowed up by the inferior quality of the iron made by its means.

However sincere these manufacturers may have been at the time in question, further experience has modified their ideas, for at the present day by far the larger number of furnaces in Wales is blown with hot air.

It is now upwards of forty years since Neilson patented his discovery, and it is not a little remarkable that this question of quality cannot be considered as entirely settled yet. If the matter had to be judged by the acts of the majority of the manufacturers, then undoubtedly it might be inferred that the present cases, so few are they, where cold blast is still adhered to, might be regarded

as the last signs of life in a struggle against speedy extinction. Large, however, as this preponderance of opinion may be in favour of hot air, it has the objection, it may be urged, of being entertained by those who may be supposed to prefer its use on account of the cheapness it has been the means of introducing into their process, and the great command it gives over the operation.

With every wish to deal fairly with the disputed point of quality its decision is surrounded with much difficulty, and is one which requires great experience, before any individual is justified in speaking with the necessary confidence even on facts capable of more speedy demonstration than those appertaining more immediately to the use and durability of the product. In illustration of this, I may observe, on referring to some early note-books of visits to the Welsh works, that the opinion was then pretty generally entertained that the whole of the advantages obtained in the blast furnace by the use of hot air was, by the waste of iron and defective quality, lost in the forge and mill.

The present generation, however, as a rule, has turned its back on the creed of its predecessor, and the advantages of hot blast, at all events as a matter of economy, is, in our time, universally admitted. As regards the alleged loss in the process of converting the pig into malleable iron, I have the indisputable authority of my friend, Mr. Menelaus, of the Dowlais Works, for stating that this is a mere illusion, and that small, comparatively speaking, as the saving of fuel in the blast furnace is in Wales (about 15 cwts.), the advantages of hot air cannot be denied by any one who has paid proper attention to the subject. This it must be recollected, is, of course, not a carelessly adopted view, but one which is the result of comparing whole years' operations conducted under the two systems.

During the recent visit of the Iron and Steel Institute to Staffordshire, I made the subject a matter of constant enquiry. I cannot say the answers received were universally in one direction, but there is no manner of doubt the large preponderance of opinion, and this from makers of immense experience, is, that from the same materials there is no appreciable difference between hot and cold blast pig nor in the malleable iron afforded by the two kinds of metal.

My experience in foreign countries leads me to believe that this is the view entertained by the great majority of those producers of

the fine descriptions of charcoal iron, whose position in the market is entirely dependent on the world-wide reputation of their limited make. With few exceptions, I found these Continental manufacturers had applied hot air to their furnaces; as, for example, in Norway and Sweden, when treating the pure magnetic oxides of these countries, in Styria and Carinthia, for smelting the fine spathose ore of Eisenerz and Lölling, and at Fullonica, when using the specular ore from the neighbouring island of Elba.

At Dannemora, it is true, they adhere to cold air, on the ground, as I was informed, that the quality of their well-known brand had suffered by an attempt to use hot air.

Professor Tunner* on the other hand, who has had large experience with the manufacture of the pure charcoal iron at Eisenerz, asserts positively that deterioration is no necessary consequence of the use of hot blast..

When such very minute quantities of certain substances, such as P, S, Si, &c., are known to be capable of affecting in an unmistakeable manner the properties of iron in which they occur, it is, perhaps, an act of over refinement to reason upon their being present in greater or less amount, from our presumed acquaintance with the nature of the smelting process, when carried on by means of air heated or otherwise.

It may be urged, and perhaps reasonably so, that our knowledge of this subject is too limited to deal satisfactorily with so delicate a matter as that in question; at the same time, we must make the best use we can of the information we possess, and the argument based thereon must be judged accordingly.

Viewing the action of the blast furnace comprehensively, I have regarded the actual work done as performed identically in the same manner, whether the air is used hot or cold. Thus, in the Lilleshall 71 feet furnaces, we have the combustion of about 28 cwts. of coke affording the necessary heat for smelting iron from an ironstone yielding 40 to 43 %, by giving the gases time enough to become saturated with O, and so to communicate their sensible heat to the descending materials, that when the latter reached the tuyeres the store of heat they contained, added to that evolved by the combustion of the fuel, sufficed for the required duty, without any heat

* Russland's Montan Industrie insbesondere dessen Eisenwesen. Leipsig, 1871.

being communicated to the blast. If the furnace, instead of having a height of 71 feet, had only 48, the work was inefficiently performed, and had either to be supplemented by the hot blast or by the consumption of a larger quantity of fuel in the manner already explained. By an increase of capacity and the use of hot air, a further economy of fuel may be effected, and this continues until the gases are fully saturated with oxygen.

In effect, then, as has been already stated, for a similar quality of iron, an identity of temperature ought to be found in every furnace, whether the air which enters it is hot or cold. If this be so, then in the matter of temperature there is no reason why iron made in either way should differ materially.

If, on the other hand, as has been and is often alleged, the effect of heated air is to detoriorate the quality of the pig iron, we might reasonably expect that this deterioration would keep some kind of pace with the elevation of temperature conferred on the blast.

In comparing hot with cold blast iron, I speak with hesitation, from my want of experience with the latter, but in dealing with iron made in furnaces blown with air at about 350°C. (662°F.) up to 500°C. (932°F.), I labour under no such disadvantage. I may, therefore, confidently state, from my own personal acquaintance with both, that the quality of the product has in no way suffered by the change from the lower to the higher of these temperatures of blast. Indeed, I may go further, and give it as my own opinion that there has been an actual improvement, which I attribute to the use of a less quantity of fuel, for, if reference is made to Section XXXV., on the behaviour of P and S in the blast furnace, it will be seen there is an appreciable quantity of both these elements in the coke. Anything, therefore, which lessens the extent to which these acknowledged hurtful ingredients enter the furnace, must be beneficial, and one cannot be surprised that the iron has not suffered by raising the temperature of the blast, accompanied, as this has been, by a diminution in the quantity of fuel.

Looking back at the figures contained in the section mentioned above, it will be seen that the phosphorus entering the furnace, when using hot air, for each 100 parts of iron produced, amounted to 1·578, and the sulphur to 4·456. Were this furnace using 3 tons of coke per ton of iron, the phosphorus would be raised to 2·055, and the sulphur to 7·3 parts per 100 of pig.

These arguments, based on the action of the blast furnace, so far as they go, would point to the conclusion that hot blast, far from acting hurtfully on the iron smelted by its aid, will produce a marked improvement by the change in its temperature. At the same time, however, we must not overlook the fact that in the hearth of the blast furnace there is constantly occurring a series of very complicated and, perhaps, not very well understood, chemical changes, which have been touched upon when speaking in Sections XXVI. and XXXIV. on the generation and decomposition of certain cyanogen salts. Whether or not slight changes in local temperature may affect the order of chemical action, which appears very active near the tuyeres, it is impossible, in our present state of knowledge, to say.

The experience in the manufacture of Bessemer steel affords some information to guide us in the consideration of this intricate problem now under consideration. If a sample of pig is delivered to the bar iron maker, containing a large percentage of phosphorus, the action of the puddling furnace removes by far the greater proportion of this substance.

Exp. 752. A specimen of pig iron was ascertained to have associated with it P 1·33 per cent.
S ·158 „
the puddled iron made from it contained, of P, ·29 per cent.; and of S, a mere trace.

Exp. 753. A second sample of pig iron, containing about 1½ per cent. of P, yielded a puddled bar, giving only ·33 per cent. of this substance.

In the Bessemer converter, no such removal of phosphorus takes place, and as its presence in quantity amounting to less than one-tenth per cent. is fatal, the steel maker has no alternative but to employ pig iron almost entirely free from this element. Sulphur, too, is equally shunned by the producer of Bessemer steel. Now, if the action of hot air, in the blast furnace, tended in any way to concentrate the quantity of either phosphorus or sulphur in pig iron, it is clear its use would be more carefully avoided in the manufacture of that intended for the steel works than that destined for the manufacture of bar iron, inasmuch as the puddling process is capable of removing partially, at all events, the phosphorus, which is not the case with the Bessemer converter. This view of

the question, of course, confines the cause of deterioration to sulphur and phosphorus. It is possible that some other ingredients may, by their presence, prejudicially affect the quality of iron, such, for example, as silicon, but I am not aware that those who advocate the use of cold blast have ever succeeded in demonstrating that the superiority of iron, so smelted, was indebted for its alleged higher excellence to the absence of any particular ingredient or ingredients found in metal produced with hot air.

At the present time, when the relative merits of the two systems of manufacture are compared, reference is very generally made to the high character of certain well-known brands of iron, which being produced exclusively by means of cold blast are regarded as affording incontrovertible proof of the superiority possessed by the ancient mode of smelting.

It is almost superfluous to say that it is in the highest degree unphilosophical to institute any comparison between hot and cold blast iron, unless in each case the minerals are precisely the same. To some extent this has been done, and it would appear that, according to the experiments of Fairbairn and Hodgkinson, already referred to, when the hot blast was applied to the minerals used at the Devon and other ironworks, there was an evident improvement in the strength of the pig iron.

At that period too little importance was attached to the chemical constitution of pig iron to have prompted any one to ascertain, by actual examination, whether any change in this respect had been induced by heating the air, and at the present day it is, so far as my enquiries go, impossible to obtain specimens of hot and cold blast iron smelted from exactly the same materials.

The nearest approach I have been able to make to this is afforded by the assistance of my friend, Mr. Walter Williams, the well-known Staffordshire ironmaster, and even here, the specimens are far from being all that is to be desired.

The cold blast iron was the produce of the Staffordshire clay ironstone, smelted with South Staffordshire coke, and with the Dudley limestone as a flux. The hot blast iron was obtained from the same Staffordshire claystone, mixed with one-sixth North Staffordshire black band, and one-sixth red hæmatite. The limestone employed in this case was from Wales, but the fuel used was the same as in the cold blast furnace. There were thus two important

deviations from identity in the materials—the ore in the hot blast furnace contained one-third of hæmatite and black band, which were not present in that blown with cold air, and the limestone was different.

So far, however, as phosphorus is concerned, as the red ore is free from this ingredient, the sixth part of black band is the only source likely to bring any addition to this element, unless the flux from Wales is richer in P than that from Dudley.

Neither of these possible causes of contamination, however, have added, practically, either to the amount of phosphorus or sulphur contained in the hot blast iron; as may be seen from the following analyses, carefully done by my present assistant, Dr. Watson. Both samples were No. 3 in quality.

	Exp. 754. Cold blast.		Exp. 755. Hot blast.	
Fe	93·761		92·201	
C, graphite ...	3·062	3·405	2·568	3·161
combined ...	·343		·593	
Si	1·025		2·080	
S	·077		·065	
P	·663		·686	
Mn	·819		1·549	
	99·750		99·742	

In these experiments, there is a considerably larger quantity of Si in the iron produced by the hot, than by the cold blast furnace. In examining some of the analyses quoted in "Watts's Dictionary of Chemistry," the Si, in some cold blast iron, exceeds even the quantity given above; thus, in specimens of Dean Forest iron, made with cold air, 2·34 and 2·10 per cent. are given as the content of Si. Knowing from my own experience, however, how irregular the quantity of Si is in metal made in our own furnaces, blown with heated air, I was not disposed to attach much importance to this; nevertheless, other pigs of the same Staffordshire iron were sampled, and these, on trial, gave results which confirmed my opinion on the uncertainty as to the existence of Si in definite quantities.

		Cold blast.			Hot blast.
Exp. 756.	No. 2 iron, Si%	1·446	Exp. 758.	No. 2 iron, Si%	2·521
„ 757.	„ „	1·294	„ 759.	„ „	1·948

The only other notable difference between the two kinds of iron was the larger proportion of manganese in that made by hot blast. The presence of this substance was more likely to be an advantage than otherwise, but, to see whether its larger presence was accidental or not, further trials were made :—

	Cold blast.		Hot blast.
Exp. 760. No. 2 iron, Mn.%	1·060	Exp. 762. No. 2 iron, Mn%	1·726
„ 761. „ 4 „ „	·953	„ 763. „ 4 „ „	1·253

These numbers indicate that the metal, in question, occurs in larger quantity in hot blast iron, made of the minerals already specified, than is found in cold blast iron, from a mixture of ore of a somewhat different character.

I have in vain sought to connect the alleged superiority in quality, said to be enjoyed by iron manufactured with cold air, with any freedom from those substances generally considered as affecting prejudicially the character of pig iron. Of course, in them, as in all iron, hot as well as cold blast, we are pretty safe in asserting that excessive quantities of Si, P, or S are hurtful, but on referring to a list of analyses in Bauerman's work on the "Metallurgy of Iron," it will be found that certain highly esteemed brands of cold blast iron appear to contain more of these substances than do others much less favourably known in the market.

Upon one occasion, the subject was made one of direct experiment at the Clarence Works. A furnace, about to be extinguished, was blown with cold air for a short time, the burden of ironstone, of course, being reduced to meet the change of circumstances. The trial was made some years ago, and the pig iron not having been submitted to analysis, I cannot speak as to its composition, but so far as the quality of bar iron it afforded is concerned, I know positively there was not the slightest trace of improvement.

It is almost needless to observe, that a belief in the absence of any advantage in the quality of iron produced by one mode of manufacture or another does not involve any doubt as to the excellence of the produce of certain works which happen to be made by means of either; all that is intended to be conveyed by the general tenor of the present remarks is, that it scarcely has been satisfactorily proved that the excellence in question is really due to the temperature of the blast used in the smelting process.

I have been given to understand that, in some establishments,

making high-class iron, when a furnace, worked with cold blast, is driven so as to produce above 90 tons a week, an unmistakeable deterioration in the quality of the bars obtained from pig iron manifests itself. Acceleration alone, in the speed of driving, may of itself give rise to an increase in the intensity of temperature evolved from a given quantity of carbon; but, at the same time, it is much more likely that the depreciation in quality, if it occurs, is due to a reduction in the actual heat of the hearth, which will be caused by a portion of the reduction being effected so low down in the furnace that the CO_2 dissolving C diminishes the weight of coke for combustion at the tuyeres, which, of course, will be followed by a lowering of temperature.

It might be inferred that when the problem to be solved was the mere determination of certain physical properties, there ought to be no difficulty in ascertaining the relative power of resistance possessed in every conceivable direction by iron, cast as well as wrought.

All this has been done, and well done, at a very early period by Fairbairn and Hodgkinson, at the request of the British Association for the advancement of Science. According to the report of these gentlemen, results were obtained of a somewhat unexpected nature; at all events, they certainly do not coincide with the relative estimation in which certain brands of iron were held, and continue to be held, in the market. The following figures are taken from one of their tables:—

	Tensile strength per square inch of section in tons.	Crushing strength per square inch of section in tons.
Low Moor No. 1, cold blast	5·667	27·003
„ No. 2, „	6·901	42·324
Bowling No. 2, „	6·032	33·507
Clyde iron No. 1, hot blast	7·198	40·535
„ No. 2, „	7·949	47·326
„ No. 3, „	10·477	47·338

The following table contains the data of different makes of pig iron manufactured by hot and cold blast, as determined by the same authorities as the preceding, in which the ratio between the two is given, cold blast being represented by 1000. From these it would

appear some irons are improved, and others are deteriorated in quality.

	Carron No. 2.	Devon No. 2.	Buffery No. 1.	Coed-Talon No. 2.	Carron No. 3.
Tensile strength	809	—	769	884	1,250
Compressive do.	1,020	—	925	1,012	1,156
Transverse do.	991	1,417	931	—	—
Power to resist impact	1,005	2,786	963	—	—
Transverse strength of inch square bars	973	1,199	942	—	—
Ultimate deflection do. in ins.	1,018	1,380	1,058	—	—
Modulus of elasticity ℔ sq. in.	931	991	893	—	—
Specific gravity	997	991	989	1,002	989

More recently, Mr. Kirkaldy has bestowed much attention on the strength of iron and steel, and the results of his investigations have been published.* From these the following numbers have been extracted to show that the more expensive irons do not exhibit a corresponding power of resistance. The specimens, Mr. Kirkaldy states, were obtained promiscuously from merchants' and engineers' stores, and in each case a rolled bar, one inch in diameter, was taken:—

Brand.	No. of expts. of each.	Breaking weight ℔ sq. in. of original area Lowest. lbs.	Highest. lbs.	Mean. lbs.
Low Moor	4	59,320	65,166	61,798
Bowling	4	58,678	65,701	62,404
Bradley	4	56,004	58,036	57,216
Govan (Scotch)	4	57,738	59,726	58,746
Govan (Scotch) B. Best	4	60,069	66,363	62,849

Later still, M. Knut Styffe, the Director of the Royal Technological Institute of Stockholm, by order of his Government, undertook a series of investigations, which are recorded in a book on the "Elasticity, Extensibility, and Tensile Strength of Iron and Steel."† In this book, information of temperatures at which fracture took place, and the carbon and phosphorus in the bars are given:—

* "Experiments on Wrought Iron and Steel," 1863.

† Translation by C. P. Sandberg. Murray, London, 1869.

Brand.	Per cent. Carbon.	Phosphorus.	Diameter of round bar. In.	Temp of bar. F.	Breaking weight per sq. in. of original area. Tons.
Low Moor (cold blast)	·21	·068	·465	− 32	27·35
„ „	„	„	„	+ 68	25·21
„ „	„	„	„	+ 59	29·10
„ „	„	„	„	+ 323	29·62
Middlesbro' (hot blast)	·07	·250	·581	− 40	27·44
„ „	—	—	—	+ 57	25·81
„ „	—	—	—	+ 60	23·58
„ „	—	—	—	+ 59	26·46
„ „	—	—	—	+ 318	31·12

The pages from which the preceding figures are extracted contain much information which would be out of place in such a work as the present. My object has not been to compare the relative value of different kinds of iron, but to show how difficult it appears to be to prove the resisting power of either cast or wrought iron by mere experiment.

It must be remembered that the researches which gave the results just quoted, by no means represent the conditions of actual use. A cube or cylinder of cast iron may have a high tensile or compressive strength, but from excessive contraction in cooling in a large casting, may be in such an unequal state of tension as to break on concussion. In like manner, bar iron may, from causes our present state of knowledge does not enable us to explain, have great tensile strength, and yet be less able than others to resist those violent shocks, to which in many cases it is exposed.

All this goes to prove that it is long experience alone which secures, and properly secures, for any particular mark that preference which commands a high price in the market, and this position it necessarily maintains against the produce of any less well known manufacturer, who, nevertheless, may possibly turn out an article in all respects equal to that of his better known rival.

My intention in this section, however, is not with this aspect of the question. It is simply to express the opinion that no satisfactory proofs have been published to show that the use of hot blast is attended with hurtful effects on iron produced by its means, while many manufacturers, well known for the quality of their make

when cold blast alone was employed, have commenced the use of hot air without injury to the character of their iron; and further, that we have the evidence of authorities like Professor Tunner in favour of the view, that whether iron is smelted by heat intercepted in the upper part of the furnace, or by fresh heat added to the blast, the resulting temperature in the hearth, I maintain, being, in all probability, the same in each case, is immaterial so far as the nature of the product is concerned.

SECTION XLI.—ON THE THEORETICAL *MINIMUM* OF FUEL REQUIRED TO PRODUCE ONE TON OF PIG IRON.

Whether the actual amount of heat required in the production of a given quantity of pig iron has been stated with rigid precision in the present work or not, there is no doubt whatever that there is absorbed in the process a certain number of calories or heat units, and no more. The difficulty of defining what this quantity really is, arises, not from there being any variation or irregularity in the smelting operation itself under a given condition of things, but from the next to impossibility of correctly ascertaining the value of the factors which constitute the elements of the calculation.

Notwithstanding this uncertainty, I am of opinion that a sufficiently accurate estimate of the measure of heat required has been made to serve all practical purposes. The absorption of heat in the blast furnace, however, is not one of a simple character, *i.e.*, it means something more than a conversion of a known number of calories into their equivalent of fuel, by even the most accurate knowledge of the calorific power of such fuel, and its power to do a certain quantity of work implied by the mere absorption of heat. As we have seen, the full calorific power of the carbon which is burnt in the blast furnace, has a restriction placed upon it by the chemical conditions attending the reduction of an oxide of iron.

Under these circumstances, it becomes necessary not only to ascertain how much heat is required for smelting iron, but we must know the precise extent to which we can look to our fuel for supplying that heat, and lying within this second branch of the enquiry, because, dependent upon it, is the subordinate one of how much of such heat must be obtained at the expense of burning fuel in the furnace, and how much may be derived from the less expensive source of having it communicated to, and conveyed by, the blast.

It has happened, upon more occasions than one, in recent discussions before the Iron and Steel Institute, that the question has been raised as to the minimum of fuel necessary for the production of a ton of iron, and what is the *maximum* useful temperature the air driven into the furnace can have.

No doubt much that can be said on these important questions has been already explained in these pages, but as the subject is one to which members of the Institute still address themselves, in their discussions, I have deemed it advisable to dedicate a distinct section to its consideration.

Before any attempt is made to ascertain how the necessary heat has to be commanded, we must agree on the exact quantity which is required, and to do this, an assumed condition of the fuel, of the atmosphere, and of the ironstone and limestone, must be taken as the basis of calculation.

For the estimate, the following will be adopted as forming the groundwork of the estimate :—

Durham coke, 100 parts, considered as consisting of—
Ash and sulphur 5 %, water 2·5 %, carbon 92·5 %.

One ton of iron will require—

Limest. 11 cwts., composed of 6·16 CaO 4·84 CO_2
Ironstone of Cleveland, calcined—49 cwts. composed of 18·6 Fe 9·00 O, and 21·4 cwts. of earths, P.S., &c.

		cwts.
Slag will weigh—ash from the quantity of coke used ...		1·10
CaO from limestone		6·16
Earths from ironstone	21·4	
Less bases, &c., taken up by pig iron, and evaporated in fume	·74	20·66
		27·92

Applying these figures to the co-efficients of absorption already accepted, we have :—

			Cwts.		Units.
For Class I., No. 1.	Evaporation of H_2O in coke		·58 ×	540 =	312
„ „ 2.	Reduction of Fe_2O_3		18·60 ×	1,780 =	33,108
„ „ 3.	Carbon impregnation		·60 ×	2,400 =	1,440
„ „ 4.	Expulsion of CO_2 from Ca O_3		11· ×	370 =	4,070
„ „ 5.	Decomposition of CO_2 in Ca O_3 ...	C	1·32 ×	3,200 =	4,224
„ „ 6.	Decomposition of H_2O in blast ...	H	·05 ×	34,000 =	1,700
„ „ 7.	P_2O_5, SO_3, and Si O_2 reduced, say			=	3,500
„ „ 8.	Fusion of pig iron		20· ×	330 =	6,600
„ „ 9.	„ slag ...		27·92 ×	550 =	15,356
					70,310
Class II., No. 10.	Transmission through walls			3,600	
„ „ 11.	Carried off by tuyere water			1,800	
„ „ 12.	Expansion of blast, &c. ...			3,700	
					9,100
					79,410

This number, 79,410, is exclusive of the quantity of sensible heat carried off in the escaping gases, which varies, of course, with their temperature and weight, hence the absorption due from this cause will be provided for in the subsequent stages of the calculation.

In the data given above, the air is taken as somewhat drier than formerly (Section XXVIII.), and the P, S, and Si in the iron as the smallest quantity usually found in Cleveland pig metal.

It may be observed that the heat absorbed in the various steps of the process was deduced, in most cases, not alone from the direct experiment of different authorities, but the amount was checked by the heat evolved by the carbon in its ascertained state of oxidation, according to the data determined by the most accurate physicists. It will be seen the difference between the two sides of the accounts (*vide* Section XXVIII.) varied from 1,560 to 3,743

units, which, in 93,455, shows a discrepancy of only from 1·6 to 4 per cent. In the same section, a table, designated one of "constant requirements" was given, in which, when smelting Cleveland stone,

28·92	cwts. coke were used	per ton of iron,	and blast at	485°C.
22·32	„	„	„	485°C.
22·00	„	„	„	780°C.

Notwithstanding the different characters of these factors, the extreme variation in the heat absorption deduced from their values was within 1·9 per cent.

In the examinations of furnace workings, which have preceded, it was estimated that the weight of carbon per ton of iron as CO_2 in the gases could not exceed 6·58 cwts., this quantity representing the deoxidation and carbon-impregnation of 18·6 cwts. of Fe, which was taken as that existing in one ton of pig iron obtained from Cleveland stone.

Admitting, then, 6·58 cwts. to be the maximum proportion of carbon per ton of iron, to be found in the gases as CO_2, we must seek to ascertain to what extent a given volume of CO can abstract the necessary O from an oxide of iron required for its conversion into CO_2. The further we can carry this absorption, and retain the heat it generates, the less carbon will be needed in the form of CO, and the more extensively can we substitute heat obtained from the combustion of coke, by that injected into the furnace along with the blast.

On referring to the greatest quantity of CO_2, given in this work, as observed in furnace gases, we find the following figures:—

	Furnace.	Cubic feet.	Vols. CO_2 per 100 vols. CO. Maximum.	Minimum.	Average.
Exp. 123.	Clarence	11,500	50	32	44
„ 132.	Clarence	25,500	45	34	40
„ 142.	Ferryhill	16,000	46	36	40
„ 147.	Ferryhill	33,000	43	30	36

In experiments 95 and 99, it was found that 100 vols. of CO, when mixed with 50 of CO_2, still possessed the power of reducing Cleveland stone, but it was so feeble that, in the former, in 5½ hours, only ·9 of the original oxygen (42·8) or 2·09 per cent., was removed; and in the latter, in 11½ hours, 4·3 (out of 42·8), or 10 per cent.; the

recorded temperature being 417°C. (782°F.) Such a temperature as 417°C. is higher than that which ought properly to be found in the escaping gases of a blast furnace, inasmuch as it would of itself involve a loss of heat which may be avoided. In the four trials just quoted it will be seen, however, that 45 to 50 vols. of CO_2 per 100 of CO have been observed in furnace gases, indicating, therefore, the power of CO to pass into the state of CO_2 to the extent of one-third its own volume, by absorbing O from Fe_2O_3. I possess no record of the actual temperature of the gases at the moment the samples containing this maximum of CO_2 were taken; indeed, this would be difficult, if not impossible, to ascertain, owing to the rapid fluctuations in the composition of the gases, and the slowness in the indications of any instrument which can be used for ascertaining the temperature. Judging, however, from a vast number of other experiments, it is highly improbable the average was below 330°C. (626°F.)

If a continuous stream of materials, mechanically and chemically speaking, the same, were flowing into a blast furnace, it is quite possible that the fluctuations, in respect to temperature and composition of the gases, would be removed. Practically, in furnaces, as they are at present constructed for taking off the gases, such a plan of charging could scarcely be pursued; nor am I prepared to admit that, were the uniformity spoken of attained, that the average in these respects would much differ from what it now is, but my present object is to show what the consumption of fuel might be, were it possible to maintain the gases at the maximum of oxygen saturation, and minimum of sensible heat, indicated in the instances just quoted.

For this estimate, 100 vols. of CO will be taken as being accompanied with 50 vols of CO_2, or by weight 100 of CO to 78·3 of CO_2. In using ironstone perfectly dry, and at the temperature of the atmosphere, it will be assumed that the heat of the escaping gases is as low as 275°C. (527°F.)

It must, however, be understood, that this assumption of a maximum saturation of oxygen, and minimum quantity of sensible heat in the gases, is merely made use of as a basis of calculation, for I shall hereafter show that, although it is easy to maintain even a much higher proportion of CO_2 than 50 vols. to 100 of CO in the gases, and it is also within our power to cool them to 275°C., it is, in

my opinion, quite impossible to command these two conditions simultaneously, and I shall also give experimental evidence to prove that as we gain by the one, we lose by the other, and *vice versa.* It must also be borne in mind that with such a large quantity of CO_2 in the gases (50 vols. to 100 CO), it required a temperature (Exps. 95 and 99) of 417°C. (782°F.) to remove the small proportion of oxygen just mentioned. At 275°, the temperature to be assumed in our calculation, it must be considered that the gases are not only practically, but are physically, saturated with oxygen, so far as they can be, when calcined Cleveland stone is the source of this element.

To proceed with the estimate, 6·58 cwts. of carbon which pass into the state of CO_2 for each ton of iron in the manner supposed is equal to 24·13 CO_2, and therefore affording, by oxidation, 52,640 units.

The actual weight of the gases containing 6·58 cwts. of C as CO_2, and consisting of CO and CO_2 in the proportion of 100 to 78·3 will be—

CO., 30·85 cwts. containing	13·22	cwts.	C
CO_2 24·13 „ do.	6·58	„	„
54·98 containing C	19·80	„	„
Of which the limestone supplied ...	1·32	„	„
Leaving to be supplied by the coke ...	18·48	„	„
Carbon taken up by the iron	·60	„	„
Total carbon in the gases derived from coke	19·08	„	„

and 19·04 of carbon is equal to 20·62 cwts. of coke containing 92·5 per cent of this element.

The figures just given will enable us to proceed to compare the heat evolution with its appropriation upon the data already set forth, as well as to determine the temperature of the blast.

The total oxygen contained in the above-named quantities of CO and CO_2 is 17·55 in the one, and 17·63 in the other, or a total of 35·18 cwts.; hence, it would appear that the oxygen is equally divided between its combination of CO and CO_2.

From the total oxygen in gases, viz., ...		35·18 cwts.
Deduct that derived from the Fe_2O_3, P_2O_5, SiO_2, and SO_3 in the ore, say	9·00	
Deduct that derived from the limestone	3·52	
Do. do. moisture in blast	·40	
		12·92 „
Leaving the blast to supply		22·26 „
Add weight of nitrogen accompanying this O		74·52 „
Moisture		·45 „
Weight of blast		97·23 „

Weight of gases—Blast	97·23	
O from ore, limestone and H_2O	12·92	
C in gases	19·80	
H_2O from coke ...	·50	
		130·45 „

The total number of calories actually required will be those given in a previous page	79,410
The total number in 130·24 cwts., gases at a temperature of 275°C. 130·24 cwts. × 275°C. × ·24SH	8,610
	88,020

The heat evolved will be as follows:—

C to CO ...	13·22 cwts.					
Less than in limestone	1·32 „					
	11·90	×	2,400	=	28,560	
C to CO_2 ...	6·58	×	8,000	=	52,640	
						81,200
	18·48					

Left to be supplied by the blast ... 6,820

and $\frac{6{,}820 \text{ units}}{97{\cdot}23 \text{ cwts.} \times {\cdot}237 \text{ SH}} = 297°\text{C. } (527°\text{F.})$

The calculation works out to a lower temperature in the blast than any ironmaster knows will suffice in practice, when using so small a quantity of coke as 20·58 cwts. This is partly owing to the fact that the gases are taken below the usual temperature at

which they leave the furnace, and partly due to the circumstance that they do not generally contain quite the full equivalent of CO_2.

These two corrections would bring up the temperature required in the air, but they do not, in any way, affect the weight of coke consumed, which, I much doubt, under the conditions assumed, will ever be reduced practically below 20½ cwts. per ton, and, to cover those irregularities so frequently mentioned upon other occasions, it is rather to be expected that for a ton of No. 3 iron it will more frequently be 21, or perhaps nearer 21½ cwts.

By the erection of enormous furnaces, and the adaptation of heating apparatus of immense power, hopes have been expressed of reducing the consumption of coke to 18, or indeed 17 cwt. per ton, of iron obtained from Cleveland stone. Now, the effect of this would be, that the CO_2, generated in the zone of reduction, would bear the ratio of about 96 parts, by weight, for each 100 of CO.* I do not pretend that a mixture consisting even of equal weights of CO and CO_2 (100 vols. CO to 64 CO_2) possesses no reducing power, but it must be very faint, and will require a higher temperature than that usually found in the gases leaving a blast furnace. This is inferred from the experiments referred to at the beginning of this section, seeing that pure CO only commences to exhibit marked action on Cleveland stone at 210°C. (410°F.)—*Vide* Exp. 17.

It does appear, however, that there is a certain amount of inconsistency in the simultaneous adoption of very large furnaces, and very high temperature of blast. The increase of dimensions afforded a reasonable prospect of permitting the gases to part with more of their sensible heat, and of becoming more thoroughly saturated with oxygen before leaving the throat, than happens when smaller dimensions are adhered to; and these actions are necessarily attended with a saving of fuel. When this augmentation in size is practicable, and very large capacity is efficacious in economizing coke, it is unnecessary to raise the temperature of the blast, inasmuch as the quantity of heat evolved from such a state of oxidation of carbon as I have supposed in the estimate, viz., 6·58 parts to CO_2 and 13·18 to CO, is equal to giving a ton of iron, as we have just

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* *Vide* Table, Section XXXII., on Composition of Gases, using different quantities of coke.

seen, with a blast of very moderate temperature, viz., 297°C. (527°F.)

It may, no doubt, be argued that further action, by a gas on an oxide of iron still possessing reducing properties, ceases, because it is cooled below that point where deoxidation is effected, and that, in consequence, it is reasonable to expect that raising the temperature of the blast would, by a general elevation of the heat of the gaseous and solid contents of the furnace, enable reduction to be effected by a mixture of CO and CO_2, which, at lower temperatures, is inert.

Of course, such a procedure would mean that the escaping gases were leaving the furnace in a more highly heated condition than before, and, hence, one advantage accruing from an enlargement of size would be at once defeated. This is a state of things, however, that would be unproductive of any real gain, *i.e.*, it would be useless to add a given number of heat units at the bottom of the furnace if the same number escaped at the top. The additional heat, therefore, to have any value, must have additional work to perform by adding a greater load of ironstone to the coke.

Inasmuch, however, as very much larger proportions of CO_2 than 50 of this gas to 100 vols. of CO have been shown to possess, under certain circumstances, well marked powers of deoxidizing Cleveland stone, it may be well to consider the nature of those circumstances with a view to see how far they can be applied to the blast furnace, when smelting this ore with coke.

In Exp. 81, CO was entirely converted into CO_2 by being passed slowly over a large excess of calcined Cleveland stone, at a temperature a little above that of melting zinc. The Fe_2O_3, however, only lost 5·25 per cent. of its O.

In Exp. 82, 100 vols. CO and 600 vols. CO_2 at a low red heat removed 5·8 per cent of the O from Cleveland calcined ore.

In Exp. 84, 100 vols. CO and 220 vols. CO_2 at a heat just visibly red absorbed 11·7 per cent. of the O in Cleveland stone.

In Exp. 85, equal volumes of CO and CO_2 formed stable compounds with various ores, at a red heat. They were reduced to Fe O, and spongy metallic iron exposed to this mixture of gases at the same time, absorbed oxygen and became Fe O.

Now, there is no doubt the furnace itself may be made to imitate the action just mentioned, *i.e.*, the issuing gases may contain a

very much larger proportion of CO_2, than that expressed by the ratio of 50 vols. to 100 of CO.

Exp. 764. Immediately after charging into the Wear furnace (17,500 cubic feet) 25 cwts. of coke, 12 cwts. of limestone, and 54 cwts. of calcined Cleveland stone, in the order in which they are mentioned, the gases were found to consist of

CO_2	8·8	CO_2 30·66 vols. for 100 vols. CO, or
CO	28·7	„ 48·06 parts by weight to 100 CO.
H	1·1	
N	61·4	
	100 vols.	

All charging was now discontinued, and the gases were sampled at intervals of 20 minutes, and afforded the following results:—

		CO_2	CO	H	N	Vols.	100 CO = CO_2 by Vols.	by Weight
Exp. 765.	end 20″.	10·7	29·2	3·3	56·8	=100	36·64	57·38
„ 766.	„ 40″.	12·3	25·2	3·8	58·7	=100	48·31	76·44
„ 767.	„ 60″.	22·2	16·9	2·1	58·8	=100	131·36	205.89

To verify the correctness of these numbers, Exps. 766 and 767 were repeated.

Now, really what takes place under such conditions as those just described, I take it, is this. After charging, any soft coke is immediately attacked, and C is dissolved at the expense of CO_2. At the Wear Works, this happens in a more striking way, perhaps, than usual, owing to the coal used there giving a softer coke. This action, however, ceases in time, and the CO_2 produced by deoxidation, not passing through any fuel, owing to the order in which the materials were charged, begins to increase as is seen in Exp. 764 and 765, in which the ratio has risen from 30·66 to 36·64 vols. This continues, and, by the end of the hour, it has become 131·36 vols., or above two and a-half times that which was adopted as the basis of the calculation to obtain the theoretical *minimum* of coke.

A great deal, however, of the heat evolved by the extraordinary proportion of CO_2 is lost, for being generated so near the point of exit, it is carried away in the escaping gases, as may be seen by the following observations:—

Clarence.	cubic ft.	Temp. °F.	Ceased charging during h. m.	Temp. °F.	Rise. °F.
Exp. 768. No. 4 fur.,	25,500	579	1 26	816	237
„ 769. „	„	564	1 20	814	250
„ 770. „	„	593	1 23	797	204
„ 771. „	„	586	1 40	788	202
„ 772. No. 5 fur.,	25,500	608	1 30	844	236
„ 773. „	„	644	1 20	834	190
„ 774. „	„	586	2 30	887	301
„ 775. „	„	629	1 42	867	238
Average rise	...	...	1 36		232=129°C.

Now the ordinary composition of the gases of the Wear furnace, when working upon the burden mentioned above was, by weight,

(*V.* Exp. 536) $\left.\begin{array}{ll} CO_2 & 14{\cdot}9 \\ CO & 28{\cdot}2 \end{array}\right\} = 52{\cdot}8$ parts by weight of CO_2 to 100 CO

$$\begin{array}{ll} N & 56{\cdot}9 \\ \hline & 100{\cdot} \end{array}$$

And, in round numbers, the calories evolved by burning the fuel used per ton of iron, viz., 23·5 cwts. (*v.* Exp. 536) would, when the gases were emitted, containing CO_2 to CO as 205 to 100, be above 30,000 more than when the oxides of carbon were as 52·8 to 100.

Practically, however, any heat thus evolved and afterwards absorbed is in part entirely wasted, because the moment charging is resumed the accumulation enables the highly-heated CO_2 to act more vigorously on the freshly added coke, and, that coke acts quickly in this way may be inferred from the following line of argument.

In Exp. 751, data were given, which showed, bulk for bulk, ironstone possessed twice the power of coke in intercepting heat when a current of hot air was blown through it, there being under the circumstances of the trial no chemical action. Now, as ironstone is about double the weight of coke, it follows that weight for weight their heat-intercepting powers are about equal. It may, therefore, be expected that apart from chemical action, if 24

cwts. of coke were introduced into a furnace it would affect the temperature of the gases by simple refrigeration to the extent of something like one-half the extent of that of 50 cwts. of ironstone, including its flux.

Exp. 776. Twenty-five observations were made on the temperature of the gases five minutes after charging 24 cwts. of coke. The fall varied considerably, but the average was 38°F. (21°C.)

Exp. 777. A similar number of trials was made after charging 50 cwts. of mine, &c. Here, too, the variation was great, but the average cooling amounted to only 23°F. (13°C.), also observed five minutes after charging.

Now, under no circumstances can the introduction of coke into the reducing zone be accompanied by an evolution of heat. Undoubtedly, it is otherwise to some extent, but not a large one with ironstone; but however this may be, five minutes would not suffice to bring it up to the necessary temperature to induce strong chemical action; so that, in the twenty-five experiments just described, we may regard it as occupying the same neutral position it did when hot air was blown through it. Admitting this, as regards the ironstone, there seems no alternative but to ascribe the increased rate of cooling exercised by the coke in the blast furnace to chemical action, *i.e.*, the high temperature of the gases expends itself by causing CO_2 to act on the carbon.

I proceeded to examine the correctness of this supposition by the following series of experiments. The fall of temperature was ascertained to be as follows, after the dinner time, during which, charging had been discontinued :—

	Temp. after dinner.	After charging three rounds, weighing 403 cwts. of coke, mine, and flux.	Time occupied. h. m.	Fall.
Exp. 778.	... 816°F.	... 572°F.	... 1 10	... 244°F.
„ 779.	... 816	... 552	... 1 30	... 264
„ 780.	... 797	... 636	... 0 50	... 161
„ 781.	... 788	... 552	... 1 0	... 236
„ 782.	... 834	... 593	... 1 0	... 241
„ 783.	... 834	... 629	... 1 40	... 205
„ 784.	... 887	... 617	... 0 50	... 270
„ 785.	... 867	... 624	... 1 0	... 243
			Average fall	... 233 =129°C.

So that the gases have fallen in temperature, after 403 cwts. were introduced to fill the furnace again, almost exactly what they had risen while charging was discontinued.

The next step was to ascertain the nature of the change which had taken place in the composition of the gases, and this is set forth in the following analyses :—

		CO_2.	CO.	H.	N.	Vols.
Exp. 786.	After ceasing to charge ...	8·8	28·7	1·1	61·4	=100
„ 787.	Before starting to charge after an interval of $1\frac{1}{4}$ hr.	22·2	16·9	2·1	58·8	=100
„ 788.	After first round ...	10·9	28·6	3·2	57·3	=100
„ 789.	„ third „ ...	8·3	30·4	2·2	59·1	=100
„ 790.	„ fourth „ ...	11·3	23·8	4·0	60·9	=100

In order to prove how immediately the high temperature, acquired during the dinner hour, causes the CO_2 to act on the coke, the following experiments were performed at the Wear furnace (17,500 cubic feet).

	Hour.	Charged.	CO_2.	CO.	H.	N.	= Vols.	Vols. CO_2 per 100 CO.
Exp. 791.	11·40	... ...	11·6	28·1	1·8	58·5	= 100	41
„ 792.	12·5	Charged 1 round coke, ironstone, &c., furnace full	10·7	not ascertained.				
„ 793.	12·30	... ...	11·7	do.				
„ 794.	12·55	... ...	19·1	18·3	0·2	62·4	= 100	105
	1·10	Charged 52 cwt. coke.						
„ 795.	1·12	No further charging ...	13·1	22·7	2·7	61·5	= 100	58
„ 796.	1·28	do. ...	11·1	25·2	1·3	62·4	= 100	44
„ 797.	2·10	do. ...	12·7	23·5	2·0	61·8	= 100	54
„ 798.	2·55	do. ...	22·7	17·8	—	59·5	= 100	128
„ 799.	3·40	do. ...	15·8	16·4	1·5	66·3	= 100	96
„ 800.	4·5	do. ...	11·8	26·7	1·2	60·3	= 100	44

In the above experiments, the furnace, on being filled up with the ordinary round, viz., coke 26 cwts., mine 54 cwts., limestone 12 cwts., the gases exhibit their ordinary composition. Nothing was filled during 1 hour 5 minutes, by which time the CO_2 had risen from 41 vols. to 105 vols. per 100 CO. Two rounds, weighing 52 cwts. coke (Exp. 795), were then let at once into the furnace, and immediately after the CO_2 fell to 58 vols., and in 18 minutes, to 44 vols. per 100 of CO. The CO_2 now began to rise again, and reached, in Exp. 798, 128 vols. per 100 of CO. No more ironstone being introduced, the CO_2 now began to fall off in quantity, and in 3 hours 55 minutes, had fallen to 44 vols. per 100 of CO.

To ascertain what the temperature really was, which sufficed for this speedy action of coke on CO_2, the following trials were instituted, also at Wear furnace.

	Hour.		CO_2	CO	H	N	Vols.	CO_2 per 100 vols. CO	Temp.
Exp. 801.	12	... ...	12·5 ...	26·4 ...	3·8 ...	57·3 =	100 ...	47·3	
,, 802.	12·13	... ...	12·0		not ascertained.				800F
	12·20	let in 26 cwt. coke							
,, 803.	12·23	... ...	...	...	...	...	...		625F
,, 804.	12·30	... ...	10·7 ...	30·6 ...	1·3 ...	57·4 =	100 ...	34·9	
,, 805.	12·45	... ...	8·4	not ascertained.			probably	30·	
,, 806.	1·35	... ...	16·7 ...	21·0 ...	1·5 ...	60·8 =	100 ...	79·5 ...	1025F.

After Exp. 802, when the coke was introduced the temperature of the gases would probably be 850°F., and the CO_2 to CO most likely as 50 to 100 vols. In three minutes after the coke entered the furnace, the temperature of the gases fell to 625°F., and they immediately afterwards contained CO_2 and CO in the ratio of probably 30 vols. to 100.

In this way, it will be perceived that there is a constant struggle between the formation of CO_2, accompanied by high temperature and the reduction of the CO_2 thus generated, back again to CO, a which latter change is, of course, effected at the expense of heat. Between these two extremes there is a middle course in which time is an important element, for the quantity of CO_2 formed, and its attendant heat, will depend upon the relative rapidity with which CO can absorb O from the Fe_2O_3 under treatment, and that at which the resulting CO_2 takes up a fresh equivalent of C. In the case of Cleveland stone the mean of the two conflicts, in my opinion, is generally reached even before the CO_2 exists in the proportions which constitute the basis of the calculation just given, viz., 50 vols. of this gas to 100 vols. of CO, and when the temperature of the escaping gases consequent upon this proportion of CO_2 is about 330°C. (626°F.) I will hereafter give a remarkable instance of a very different rate of fuel consumption from that obtainable when the ironstone of Cleveland is the ore used in the blast furnace, and an attempt will be made to explain the cause of this modification in the progress of the action.

If, then, accompanying a given quantity of heat required for the production of a ton of pig iron, a certain quantity of CO must be present, it follows as a matter of course that any heat contributed

by that contained in the blast will be useless, which when it is added to that generated by the formation of the CO rendered necessary by the nature of the process, the sum of the two exceeds that shown to be required. I have endeavoured to prove what becomes of this surplus of heat, viz., that it passes off in the escaping gases, or it is expended in the CO_2, formed in the upper zone of the furnace, absorbing C.

The second branch of the enquiry, viz., the *maximum* temperature the blast ought to have to permit its profitable application, is dependent entirely on the extent to which the permanent state of oxidation of CO to CO_2 is maintained. If it can be carried to such a point that the whole of the CO_2 due to deoxidation and carbon impregnation escapes as such, and that 100 vols. of CO can restrain the oxidizing influence of 50 vols. CO_2, then I have shown with the escaping gases at a temperature of 275°C. the air only requires to be heated to 297°C. (527°F.) to supply the deficiency of heat.

To effect this, however, the whole of the conditions must be favourable in the highest degree. The coke must be of that quality as to resist the power of heated CO_2 to dissolve it, and the gases must be prevented acquiring a temperature beyond 275°C. All this is attended with much difficulty, so much, indeed, that it far oftener happens that the total C escaping is not much above 6·0 cwts. as CO_2, and the CO_2 to CO is as 40 or 45 vols. to 100, or as 62·7 to 100 by weight, with a temperature of 330°C.

Now the difference between such a state of working, and that which has been hypothetically assumed as the basis of the calculation which brought out 20·62 cwts., burnt with the blast at 297°C. as being the quantity of coke required to produce one ton of iron, will be somewhat as follows. There will be a loss of ·58 cwts. of carbon burnt to CO instead of CO_2 equal to (·58 × 5,600) 3,248 calories, and the gases escaping at 330°C., instead of 275°, will represent about 1,700 units, making together, say 4,900 to 5,000 units. If the coke remained as it was, viz., 20·62 cwts., there would be nearly 5,000 units to be conveyed by 97·23 cwts. of blast, which represents an increase of temperature of about 190°C., making the total 502°C. (935°F). In practice, however, the diminution of CO_2 in the gases affects the quantity of carbon to be burnt at the tuyeres where at all events, the heat evolved is more readily rendered available by interception, hence the actual loss arising from the

causes now under consideration, is more generally to be met partly by a little more coke as well as by an increase in the temperature of the blast.

The manner in which defects of so varying a character have to be provided for, scarcely admits of very precise estimation. It must, in consequence, rather be the result of general experience than that of any formula of figures. Regarded in this way, I would give it as my own opinion that taking the ordinary run of Durham coke and Cleveland ironstone, the ironmaster who produces a ton of No. 3 iron with $21\frac{1}{2}$ cwts., with the blast heated to 500°C. (932°F.) may consider himself as working very closely up to those limits of economy which are prescribed by the nature of the materials he is operating upon.

Independently of any increase of temperature in the upper portion of the furnace, the use of the hot blast introduces a change in the relation between the solid and gaseous contents, which will have the effect of accelerating the tendency towards an equalization of temperature of the two. By this action the ore is more speedily heated, and the gases, in consequence, are more quickly saturated with oxygen gas. This arises from the longer retention in the furnace of the carbonic oxide evolved by the combustion of a given weight of coke, and this happens in the following way:—

Let us imagine that a furnace of 6,000 cubic feet has conveyed into it, by means of the hot blast, 14,400 cwt. heat units per ton of iron, over and above the number it would receive were the air driven into it at the temperature of the atmosphere. This is equal to the heat from 6 cwts. of carbon burnt to CO, which C can therefore at once be withdrawn from the fuel introduced with the charges.

This quantity of carbon represents in resulting gases (C, 6; O, 8; N, 26·8) 38·8 cwts.

This is equivalent to a reduction of nearly 10 per cent. in the volume of the gases flowing up through the contents of a furnace using originally 60 cwts. of coke per ton of iron. During the time, therefore, each cwt. of carbon is engaged in fusing the iron and slag in the hearth, while in the act of being converted into carbonic oxide, the CO thus formed is retained, by the diminution in its volume, one-tenth longer period in the furnace, and by so much its

contact with the materials it has to heat and to reduce is prolonged. This effects a further saving of fuel, and, in consequence, a further reduction in the volume of gas is accompanied again by an addition to the time of retention of this gas in the furnace. This is continued until the fuel is diminished in quantity, as far as a furnace of the supposed dimensions is capable of producing a ton of iron, which is not reached until the gases in bulk are a mere trifle above one-half what they were when the blast consisted of cold air, instead of with the supposed addition of the 14,400 units in question.

It is clear, under such circumstances, the reducing gases will be twice as long in contact with the ore they have to reduce, and with the materials they have to heat, as when cold blast is employed.

That it is time alone which effects the change, and no mysterious virtue in the heat of the blast, is proved, I submit, beyond all doubt, by the fact that precisely the same results, in point of fuel consumed, are obtained by a suitable enlargement in the dimensions of the furnace, by which prolonged contact between the gases and solids is, in like manner, secured.

Before concluding this section on the economy of fuel, I would briefly notice a plan recommended by Mr. C. Schinz, in his work on the blast furnace,* and which he has patented under the title of "A process for partly eliminating the nitrogen in the products of combustion."

Half the schemes intended to improve the smelting of iron are propounded by persons who, neither by practice nor study, have endeavoured to make themselves acquainted with the principles upon which it is dependent. To this class, Mr. C. Schinz is a striking exception, for he has taken infinite pains to convince himself of the soundness of his project, and yet I entertain little hope of its sharing a different fate from many of its less studied predecessors.

The plan, in reality, consists of forcing carbonic oxide, obtained in one or two different ways, into the blast furnace; but, apparently, the one, preferred by the inventor, consists in heating refuse coke and carbonate of lime in retorts similar to those employed in a gas manufactory.

* "Dokumente betreffend den Hohofen."

I am at a loss to know from what quarter refuse coke has to be obtained, in sufficient quantity, to constitute an important saving in the fuel consumed in iron smelting; but, omitting this difficulty, I cannot see how an elimination of nitrogen, partial or entire, can produce any notable economy in the quantity of fuel required for the process. The production of CO, containing the necessary quantity of carbon, would require an enormous establishment, and a great expenditure in labour and in heat, exceeding the value of its equivalent weight in coke, and, after all, we obtain a fuel, CO, which the nature of the process would not permit us to oxidize at the tuyeres. Independently of all this, calculation would show that the absorption of heat in decomposing carbonate of lime and resolving its CO_2 into CO, is so great as to present an insuperable barrier to our being able, profitably, to avail ourselves of Mr. C. Schinz's proposal.

SECTION XLII.—SUPPLEMENTARY REMARKS ON THE ACTION OF THE BLAST FURNACE, IN CONNECTION WITH ITS DIMENSIONS, AND THE USE OF SUPER-HEATED AIR.

In an operation, involving so many disturbing causes as the smelting of iron, it cannot be a matter of surprise that there should, in the minds of even the most observant and experienced men, occur some differences of opinion. These differences can only be reconciled by a continuous system of observation and experiment, and as some branches of the question have only in recent times occupied a proper amount of attention at the hands of British ironmasters, it is a subject which, in reality, may be said only to have begun to make a certain amount of progress, in this country, within the last year or two. Having arrived at the concluding portion of my labours, I have deemed it desirable, before closing them, to add a chapter, which should contain, if needful, any modification of those views directly affecting the main object of my enquiry when these researches were first undertaken.

The conclusion to which I have arrived, viz., that the point of economy of fuel, attained by the Cleveland smelters in their gigantic furnaces, fed with highly-heated air, had almost reached its limit, occupied, only very recently, the attention of the members of two societies, well qualified to discuss it—I mean, the Institution of Civil Engineers, and the Iron and Steel Institute.* Upon those occasions, it was maintained, that there was still room for improvement by a further enlargement of our furnaces, provided we altered their shape, and that the utmost practicable intensity of heat should be conferred upon our blast, if we wished to reduce the consumption of coke to the lowest point.

Looking at the present high price of this article, no one will doubt the earnestness of the wish of its largest consumers to see the quantity required for their work reduced to a minimum; but this desire may lead those who entertain it to needless expense, and it therefore becomes more necessary than ever that the iron-furnace owner, interested, as he is in the subject, should consider it, in all its bearings, in reference to his own process.

Among those who have studied the application of superheated air, Mr. Thomas Whitwell occupies, deservedly, a very conspicuous place, from his personal labours in adapting it to furnaces of several sizes, and from having observed its effects upon different kinds of ore. The experience thus gained, Mr. Whitwell has not concealed from his colleagues in the iron trade; and I would therefore claim attention to the last of his communications to the Iron and Steel Institute, read before its members at their meeting in Dudley.†

This paper, to some extent, is a reply to certain statements I had made in Section XXXI., on the results obtained by the use of superheated air to the Consett furnaces, 55 feet high, engaged in smelting a mixture of hæmatite and Cleveland stone. It concludes with asserting :—

1st. "That the increase in production in the furnace, No. IV., at Consett, is directly in proportion to the increase in the amount of blast thrown into the furnace, and not consequent on the reduction of temperature.

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* *Vide* "Minutes of Proceedings of Institution of Civil Engineers, 1871," and "Journal of Iron and Steel Institute, November, 1871."

†"Further Results from the use of the Hot-Blast Fire-brick Stoves."—"Journal of the Iron and Steel Institute, Vol. II., p. 217."

2nd. "That other things, such as the action of the materials in charging, and form of furnace being equal, a regularity of quality in the iron is in no degree incompatible with a high degree of temperature in the blast.

3rd. "That in the two furnaces at Consett, under consideration, although there is a great difference in the internal form and capacity, yet no reduction of temperature in the blast has been attended with economy; but that, in both cases, a reduction of 200°F. in the temperature of the blast, has been attended by an increase of upwards of 2 cwts. in the consumption of coke per ton of iron."

By the favour of Mr. Jenkins and the Directors of the Consett Iron Company, Limited, I have had an opportunity of examining the statements from which these conclusions are drawn, and, which, according to Mr. Whitwell, "prove, beyond all doubt, that *reduction in temperature*, at Consett, so far as coke is concerned, has been followed by *increased consumption*."

Now, I am not prepared to deny—on the contrary, I have, on more occasions than one admitted—that the use of superheated air, at Consett, may have been very beneficial, looking at the character of minerals smelted in such furnaces as those at this establishment. I would further take this opportunity of stating that to the principle of the fire-brick stove, I have not only no objection, but on the contrary, I believe, for durability, for economy of fuel, and for opposing the least possible amount of resistance to the blast, it has, taken as a whole, no equal. For the present state of perfection to which this form of hot-air apparatus has been brought, we are entirely indebted to the perseverance and ingenuity of Mr. E. A. Cowper, Mr. Charles Cochrane, and Mr. Thomas Whitwell. My business, however, is with the chemical effect alone of superheated air in the blast furnace. I am quite ready to leave the question of mechanical appliances, and cost of construction of this invention, to engineers, but it is quite impossible, consistently with the enquiry I have, in undertaking the present work, proposed to myself, to avoid examining, as well as I am able, the advantages or disadvantages of the use of air at more elevated temperatures. The designers of the fire-brick stove ought to rest satisfied with recommending it for the purpose of heating the blast as high as chemistry, and, I believe, as experience show to be useful; and not confine themselves to urging its adoption, merely

because it possesses, to an extent far beyond the reach of iron stoves, the power of superheating air.

If the Exps. 33, 35, 43, and 44, are referred to, it will be seen that when hæmatite and Cleveland stone were exposed to the reducing action of CO, or of mixtures of CO and CO_2, the former always gave up its oxygen, and became charged with deposited carbon much more speedily than calcined Cleveland stone.

	Time of exposure.	Temperature.	Gas.	Lost of original O per cent. Hæma-tite.	Lost of original O per cent. Calc. Clevel'd.
Exps. 43 and 44.	$7\frac{1}{2}$ hrs. ...	410°C.(770°F.)	pure CO...	57·4...	20·7
„ 33 and 35.	6 „ quick current.	410°C.(770°F.)	„	...70·9...	50·6

In each case, the two descriptions of ore were exposed simultaneously in the lead bath arrangement.

This difference in susceptibility to reduction, leads us to the inference that a much smaller furnace may suffice for smelting the one than the other of these minerals, for reasons already given in a previous section. It is, perhaps, not very easy to adduce absolute proof as to the cause of unnecessary height in a furnace actually being prejudicial. It is, however, not difficult to suppose that the ore itself, being in small pieces, naturally, or split up into the coarse powder, attending its impregnation by carbon, may assume such a position in relation to the coke as to permit the formation of channels, and, in consequence, the too ready exit of the reducing gases. This, however, is certain, the Consett Company built a furnace, about 70 feet high, to smelt the mixture of hæmatite and Cleveland stone, treated so successfully in those of 55 feet furnished with the fire-brick stoves, and were compelled to reduce its dimensions.

We have, further, the admitted fact, that when the Consett Iron Company smelted this mixture of minerals in a 55 feet furnace, with air heated only to 454°C. (850°F.) (*vide* Section XXVIII.), the consumption of coke was more than 4 cwt. in excess of that used when the blast had a temperature of 718°C. (1,324°F.) These circumstances render it impossible to deny the importance of the service which Mr. Whitwell has rendered in this particular instance.

It would, indeed, appear that there exists some difficulty in the treatment of these rich Lancashire ores in furnaces of the more

modern dimensions, which may require further examination and study; but, at the same time, even those of the lesser construction scarcely enable this mineral to be smelted with as small an amount of fuel as one might expect.

At Barrow, for example, some of the furnaces are 46 feet, and others, 56 feet high. I have been given to understand that the consumption of coke, per ton of iron, was as small in those of the lesser description as in the larger. More recently, at the same establishment, a furnace, having a height of 75 feet, has been erected, and so unmanageable did it prove, that 14 feet have been removed from the top, so that it is now only 61 feet high, and is working satisfactorily.

At Askam, again, we have a furnace, 67 feet high, with a capacity of 13,100 cubic feet, which, from a paper by Mr. W. Crossley, read before the Institution of Mechanical Engineers,* does not appear to be performing its duty as advantageously as those at Barrow, containing 9,000 to 10,000 cubic feet.

None of these furnaces, however, afford such good results as those in the Cleveland district, having regard to the superior richness of the Lancashire ore. Thus, according to the data supplied by Mr. Crossley, which contain the most ample information we have yet received on the treatment of this description of mineral, the heat, compared with that absorbed in the smelting of Cleveland ironstone, is as follows:—

Less $CaCO_3$ to decompose (9, instead of 12 cwts.)	$3 \times 370 =$	1,110
„ CO_2 from $CaCO_3$, dissolving C ...	$\cdot 36 \times 3{,}200 =$	1,152
„ P_2O_5 to decompose	$=$	1,500
„ slag to fuse (15 cwts., instead of 30 cwts.)	$15 \times 550 =$	8,250
Total less cwt. calories required, per ton of iron, from Lancashire than from Cleveland ore		12,012

This number of calories evolved, when using a well-heated blast, say, 485°C. (905°F.), at the tuyeres, is equal to about 4 cwts. of coke.

Now, taking 21½ cwts. to 22 cwts. of coke to represent the consumption, on the banks of the Tees, for each ton of No. 3, we

* *Vide* Proceedings, July, 1871.

have $17\frac{1}{2}$ to 18 cwts. as the quantity which ought to be that for obtaining the same quality of metal on the West coast, which is, I understand, below that generally heard of in that district.

Now, in the Consett furnace, No. 4, when the minerals used are employed in such proportions that one half the iron is due to hæmatite, and the other half is due to Cleveland stone, the average over 14 months is about $19\frac{1}{2}$ cwts. of coke for metal, a shade under No. 4. If we take that due to the Yorkshire ironstone at $20\frac{1}{2}$ cwts. per ton of No. 4 iron, we have $18\frac{1}{2}$ cwts. left for the production of the metal from the Lancashire mineral; and, so far, the Whitwell stoves have done for hæmatite, when mixed with Cleveland stone, that which, when using the former alone, has, it seems, not always been accomplished in the Cumberland and Lancashire furnaces.

Referring, again, to Mr. Crossley's paper: as the West country hæmatites are, according to my experiments, more susceptible to the action of CO, it is remarkable how poor the gases from the Askham furnaces appear to be in CO_2, which gas, of course, is the indication of efficient working.

Analysis of Askam escaping gases, using $22\frac{3}{4}$ cwts. coke.

N ...	54·51 vols.	...	52·59 by weight.	
CO ...	34·97 „	...	33·80	„
CO_2...	8·36 „	...	13·47	„
H ...	2·16 „	...	·14	„
	100·00 „		100·00	„

100 CO = CO_2 24· by vol. 39·84 by weight.

When this comparatively small quantity of carbon, escaping as CO_2, is made the basis of calculating the heat development, it is easy to find why—although 12,000 cwts. calories less are required in smelting Lancashire ore—no saving in fuel accompanies this easier rate of reduction. Estimated upon a ton of iron, Mr. Crossley mentions that 4·36 cwts. of C only (instead of 6·5 cwts.) escape as CO_2, being thus 2·14 cwts. less than are found in the furnace gases, near Middlesbrough. The loss of heat from this cause is (2·14 × 5,600) 11,984 units.

When it is remembered in the experiments described in these pages, that hæmatite ore is more easily reduced than that of the Cleveland Hills, one is scarcely prepared for the less perfect mode of working just alluded to. It happens, however, so uniformly, and

this in furnaces of different sizes, that the conclusion seems irresistible that it is due to some property inherent in the ore itself. The actual deficiency of CO_2, representing the deoxidation of the $Fe_2 O_3$, leads one to suppose that the ore gets very speedily broken up, probably by the facility with which it absorbs carbon,* and, in a half-reduced state, runs down through the coke, and, arriving in a highly-heated region, a loss of fuel ensues by the action of CO_2 on the C. If, however, it is mixed with large blocks of Cleveland stone, this rapid descent may possibly be prevented, and the operation effected without this waste of heat.

Granting the merit due to Mr. Whitwell of having succeeded, by the Consett mode of treatment, in doing that which has not been done in respect to coke consumption by the smelters of pure hæmatite themselves, I still am unshaken in the belief that, having regard to the richness of the burden used at Consett, the consumption of fuel was no less than it ought to be, were it treated in furnaces 80 feet high with air less highly heated, as indeed was proved by experience at the Eston Works, mentioned in Section XXXI.

Mr. Whitwell, in No. 3 of his conclusions, endeavours to show the fallacy of my former arguments by stating that, as the blast is lowered 200°F., there is an increase of 2 cwts. in the consumption of coke.

There is an obvious error in this statement, unless it could be shown that, along with this increment in the temperature of the blast, there was also a larger generation of CO_2 in the upper part of the furnace, whereas the analyses of the Consett gases prove the reverse to have happened.

	Exp. 807. No. 4 Furnace.	Exp. 808. No. 4 Furnace.
Temperature of blast	1,107°F.	1,324°F.
Composition escaping gases—		
CO_2	14·2	11·7
CO	31·2	29·17
H	1·3	...
N	53·3	59·13
	100·	100·
100 vols. CO = Vols CO_2	45·5	40·2

* *Vide* Exp. 213. Lanc. Hæmatite—100 Fe absorbed 65·3 C in 7½ hours at 415° C.
Do. do. 214. Do. do. 100 Fe absorbed 531· C in 7½ hours at 415° C.
Do. do. 215. Cleve. calcd. stone—100 Fe absorbed 4·68 C in 7½ hours at 415° C.

Omitting the loss of heat from the deficiency of CO_2, it is easy to compare the heat evolved from 2 cwts. of coke with that represented by 200°F. in the blast.

The weight of air, using 19 cwts. of coke per ton of iron, will be about 90 cwts., which, for every 200°F. (111°C.), contains (90 cwts. × 111°C. × ·237 Sp H) 2,367 calories. Now, 2 cwts. of coke burnt to CO with blast at, say, only 600°C., is as follows :—

	Coke.				
Air to burn	2 cwts.	11·5 cwts. × 600°C. × ·237 Sp H	=	1,635	calories.
„	2 cwts.	= 1·9 carbon × 2,400	=	4,560	„
		Together ...	...	6,195	„

It is, therefore, highly improbable that the substitution of 2,367 calories, contributed by the blast, would permit the suppression of 6,195, afforded by the coke. I do not, of course, for one moment doubt, that so candid a writer as Mr. Whitwell can produce many weeks' workings which will support his own views; but they will be found to arise from some of those exceptional circumstances, of which he makes mention in his paper, and which, probably, might be explained by a reference to the "composition of the gases," to which, in my opinion, he attaches too little importance.

It seems to me, however, that the figures, quoted by Mr. Whitwell himself, by no means present that invariable coincidence between the quantity of coke consumed and the temperature of the blast, as to justify the conclusion he so unflinchingly maintains.

Instead of following the periods quoted in a table, given in the paper, in their chronological order, I have arranged them according to their temperature, beginning at the highest, and attached to each is the coke used per ton of metal. It will be perceived that no such uniform correspondence, as he supposes, is found to exist.

Period.	Temp. F.	Coke. Cwts.	q.	lbs.	Average weeks' make.	Average number.
April 10, 1869, to Aug. 27, 1870	1,400	18	0	8	388	4·47
Feb. 25 ... „ Mar. 11, 1871	1,239	19	3	23	471	4·36
Mar. 11 ... „ Apr. 8, 1871	1,225	19	1	17	500	4·14
Aug. 27 ... „ Nov. 19, 1870	1,200	18	1	19	466	4·43
Nov. 19, 1870, „ Feb. 11, 1871	1,190	20	0	17	460	4·41
April 8 ... „ May 6, 1871	1,175	19	1	15	508	4·09
May 6 ... „ June 6, 1871	1,149	19	1	4	542	not given.
Feb. 11 ... „ Feb. 25, 1871	1,148	20	0	2	467	4·43

I would only point out here, that, with the blast given at 1,175

and 1,149°F., the coke used is 19.1.15 and 19.1.4, respectively, against 19.1.17, with the blast at 1,225°F.

I may add, I have gone carefully over 45 consecutive weeks' workings of this furnace, and classified the temperatures in the same manner as that followed above, and a still greater amount of variation is apparent. To avoid any unfair inference being drawn, I have arranged them in four divisions, so as to obtain a mean consumption of coke over as many average temperatures.

Consumption of coke at Consett, No. 4 *Furnace, part* 1870 *and part* 1871.

Temperatures under 1,150°F. 15 *weeks*:—

Temp.	Coke. Cwts.	qrs.	lbs.	Iron. Tons.
1061	22	0	14	460
1098	18	0	21	484
1106	22	3	12	455
1112	18	2	26	465
1122	17	2	17	477
1126	19	0	3	513
1132	19	1	20	532
1133	20	2	15	437
1133	19	2	26	452
1134	17	0	18	467
1140	20	1	6	447
1144	19	0	19	435
1145	19	2	9	488
1148	19	2	13	491
1149	19	1	18	483

Average—

Temp. F.	Coke. Cwts. q. lbs.	Iron. Tons.	Yield ore per cent.
1125	19 2 8	472	45·63

Temperatures between 1,150 *and* 1,200°F. 16 *weeks*:—

Temp.	Cwts.	qrs.	lbs.	Tons.
1152	18	3	4	537
1158	19	1	25	476
1170	19	1	19	543
1172	18	3	20	539
1173	19	0	1	483
1174	19	3	23	455
1176	19	2	10	507
1177	19	3	22	415
1178	19	0	19	476
1181	19	1	27	462
1183	22	3	7	201
1183	19	3	24	491
1184	20	2	1	455
1184	19	1	1	456
1194	19	1	26	495
1199	19	1	9	503

Average—

Temp. F.	Coke. Cwts. q. lbs.	Iron. Tons.	Yield ore per cent.
1177	19 2 4	468	46·27

Temperatures between 1,200 *and* 1,250°F. 12 *weeks*:—

Temp.	Coke. Cwts.	qrs.	lbs.	Iron, Tons.
1201	18	1	24	506
1201	19	0	13	577
1208	20	2	23	465
1208	19	0	21	470
1208	18	3	14	462
1219	19	0	22	510
1230	19	0	26	511
1236	18	3	3	470
1236	20	2	1	478
1236	19	0	19	478
1243	19	3	19	482
1245	20	1	19	468

Average—

Temp. F.	Coke. Cwts. q. lbs.	Iron. Tons.	Yield ore per cent.
1221	19 2 4	491	46·41

Temperatures 1,250°F., *and above.* 4 *weeks* :—

1260	19	1	18	484
1283	20	0	20	508
1292	17	2	8	431
1316	19	2	4	504

Average—

Temp. F.	Coke. Cwts. q. lbs.	Iron. Tons.	Yield ore per cent.
1288	19 0 19	457	45·49

For a furnace of the size of this, 55 feet high, the make is remarkably good, but an inspection of the figures will fail to connect it with the highest ranges of temperature, and still less is the alleged saving of 2 cwts. of coke for every 200°F. of temperature in the blast perceptible. My own impression is that, if the furnace had been blown throughout at 1,100°F. to 1,150°F., probably just as good results would have been obtained as those got by heating the air to 1,300°F., but of this any one can judge for himself. The iron made was all forge, chiefly No. 4, the average being about 4·33, and to satisfy myself that the coke consumption account was not influenced by any differences in the richness of the minerals, each division, upon which the averages are calculated, contains a note of the yield reckoned upon the hæmatite and calcined Cleveland stone which was used. I shall, in the next section, have to direct attention to a somewhat remarkable case of economical use of combustible at Eisenerz in Styria, of which the particulars will be given at the proper time. At present, however, I may observe that in former years the blast at Eisenerz was only heated to 200°C. (392°F.) On receiving intimation of what had been accomplished in the vicinity of Middlesbrough, my friend, Prof. Tunner, recommended an increase in the temperature of the air, at the Styrian Works, which was

raised to 400°C. (752°F.) The weight of fuel used does not appear to have been materially affected by the change.

There has been going on, for some months past, a very important experiment at the Ormesby Works, near Middlesbrough, of which no doubt the iron trade will look for the details with great interest —I mean that connected with the huge furnace, 90 feet high, with boshes of 30 feet, and containing above 40,000 cubic feet. It receives its hot air from a range of magnificent fire-brick stoves, each 50 feet high, admirably arranged, and so powerful that upon one occasion I found the indicated temperature was 1,350 and 1,400°F. One cannot be surprised that so gigantic a piece of apparatus should have presented some difficulties on first starting it, and in consequence its designer, Mr. Charles Cochrane, is unable, he informs me, yet to speak positively as to its performance.

Since writing the preceding portion of this section, by the assistance of Mr. J. T. Smith, of the Barrow Works, very willingly rendered, I am placed in possession of facts bearing directly, and in a very conclusive manner, upon the oft-debated subject of the value of superheated air.

Some time ago, at this establishment, there was erected a new furnace, 75 feet high, with boshes of 19 feet, receiving its blast from a range of fire-brick stoves, erected from the designs of Mr. Cowper. When set to work, it proved so unmanageable in smelting the Lancashire hæmatite that it had to be stopped, and its height reduced to 61 feet. This alteration removed all difficulty, and the furnace now performs its duty with superheated blast with ease.*

After it was at regular work, Mr. Smith kindly undertook to register the temperature every half-hour for sixteen days. This varied from 1,075 to 1,125°F., with one exception, when it fell to 1,000 and rose to 1,150°F., during six hours. We may, therefore, take the average at 1,100°F. (593°C.)

In the sixteen days, the make was 1,189 tons, average No. 2·25

Coke consumed per ton of iron		...	Cwts.	20·08
Limestone	ditto.	...	„	7·61

I estimate, instead of having about 29 cwts. of slag per ton of iron, there would only be about 11 cwts. in the case we are considering,

* This is the same furnace already alluded to in the present section.

and instead of the liberated CO_2 of the limestone carrying off 1·4 cwts. of carbon (by $CO_2 \times C = 2\ CO$) only ·91 cwts. would so escape. These two differences are equivalent to 3 to 4 cwts. of coke, *i.e.*, a furnace using Cleveland stone making a ton of No. 2·25 iron with 23·08 to 24·08 cwts., would be working as well as this furnace; hence, I infer that 108°C. (226°F.)* in this case has either been uselessly expended, or because the mechanical difficulties connected with the treatment of ore in a lofty furnace are such as to compel the use of a smaller one. To overcome this defect a high temperature of blast is required.

I do not possess the necessary data to form an exact estimate to show which of these two explanations is the correct one; but an approximate calculation may be made on the basis of the gases having the same temperature, and being as highly charged with O as those in the Middlesbrough district, using their usual quantity of coke.

Fuel consumed per ton of iron ...	20·08		
Less impurity 6 per cent. ...	1·20		
		18·88	
C in Limestone carrying off equal weight from fuel ($CO_2 \times C = 2\ CO$)		·91	
			Cwt. units.
		17·97 × 2,400	= 43,128
C of the CO burnt to CO_2, say		6·5 × 5,600	= 36,400
Heat in 95 cwts. of blast (95 × 593°C × ·237 Sp. H)			= 13,342
			92,960

Now, if we take 93,000 cwt. heat units as the absorption (*vide* Section XXVII.) for making Cleveland iron, 80,000 to 82,000 should have been ample, after allowing for the lesser weight of slag and limestone, in producing hæmatite iron. Under these circumstances it seems pretty evident that, as in the Consett furnaces using superheated air, and in the Askam furnaces using air moderately heated, about 2 cwts. of C, which ought to

* The 108°C. is the difference between the temperature usually employed at the Clarence Works (485°) and that being used during the above exp. (593°).

have left the furnace as CO_2, have been reduced to the condition of CO.*

That which the incompleteness of the data in the above estimate leaves in doubt is, however, fully explained by the succeeding observations of Mr. Smith, at the furnace just described.

The actual heat required to make a ton of hæmatite iron is some 10,000 to 12,000 calories less than that capable of being evolved by 20·08 cwts. of coke, burnt with air at 593°C., provided 6·5 cwts. of C escaped as CO_2. Either this proportion of the oxidizing gas (CO_2) is incompatible with the reduction of Lancashire ore used at Barrow, or the temperature of the blast has reduced it to CO. The next experiment of Mr. Smith inclines me to the latter belief. In it, the blast was maintained steadily at 1,450°F. to 1,550°F., say an average of 1500°F. (815°C.), or 400°F. (222°C.) above that of the former trial.

Now this afforded a proper opportunity to test the accuracy of Mr. T. Whitwell's assertion, that 200°F. was equal to 2 cwts. of coke—for we have the furnace, with its blast already at 1,100°F., making iron with even an excess of coke, compared with the duty performed by a Cleveland furnace of 80 feet, fed with air at about 900°F. Surely the virtue of the 400°F. just added ought to have made itself felt in such a case as the present.

The reply shall be given in Mr. Smith's own words, contained in his letter of 16th December, 1871 :—

"I think we may consider the experiment has lasted long enough to prove that the excessive temperature (1,450°F. to 1,550°F.) had no effect whatever in reducing the coke, and the results of the eight days are as nearly as possible identical with the previous sixteen.† The make of the furnace has been 604 tons, the consumption of coke 610 tons, and of limestone 230 tons, and the ore has yielded 55 per cent. To look at the question in a more practical form, I may mention that during the 24 days the charge was never altered in any way, and when the high heat had commenced, there

* Amount of calories evolved by supposed combustion of 20·08 cwts. coke	92,960
Deduct 2 cwts. less C supposed to escape as CO instead of CO_2, $2 \times 5,600$	11,200
Leaving	81,760

† Blast at 1075°F. to 1125°F., average 1100°F.

was no difference whatever, either as to the cinder or qualities of iron."*

It would have been satisfactory to have been able to confirm the opinions just quoted, by the exact figures obtained from the performance of the Carlton furnaces, heated by means of stoves built under the superintendence of Mr. Whitwell himself. Mr. Ramsay, the director of this establishment, not having had an opportunity of extracting these, I can only quote from the general information which this gentleman has kindly given. The furnaces themselves are 85 feet high, with boshes of 18 feet, and are working with a stone which in its calcined state yields only 38 per cent. Making allowance for the difference of circumstances involved in these conditions, they have, in none of the frequent communications Mr. Ramsay has made to me, been performing better (less consumption of fuel) than works using precisely the same ore, and getting their blast at 485°C. (905°F.), although at Carlton the indicated temperature was 1,300°F. to 1,400°F. In addition to this, when a second furnace was receiving its air at 950°F., it was doing its work about as well as the other, at which the blast was heated to 1,350°F., and further, when this second furnace had its air raised to 1,200°F., little or no improvement was perceptible.

At another place in the neighbourhood of Middlesbrough, the same ironstone is treated as that used at the Carlton Works. In this case, the furnaces are blown with air heated in the ordinary cast iron stoves, and I have good authority for stating that the coke consumed at the one is within a mere fraction of that used at the other.

After explaining the laws which appear to me to regulate the action of the blast furnace, I have quoted many instances of actual workings in confirmation of the views which have been laid down. These have led me to express with some degree of confidence that it is useless to hope to smelt a ton of grey iron from the Cleveland stone yielding 41 per cent. of pig metal with anything notably under $20\frac{1}{2}$ cwts. of coke.

Notwithstanding this, it is only right to state that there are heard of in the North of England occasional instances of the work

* 604 tons of iron for 610 tons coke = 20·18 cwts. per ton.
230 ,, limestone = 7·60 ,, ,,

having been done with less even than 19 cwts., and as these were communicated to me by firms whose word is not to be questioned, I think it proper not to withhold facts merely because they may raise a doubt upon the correctness of my own assumptions.

When, however, those tests are applied, which, under the variety of conditions described in Section XXVIII., brought out such a coincidence of results, there is found considerable discrepancies attending the working of furnaces with, what I feel justified in designating as, abnormal quantities of fuel.

In illustration of this, I would dwell briefly upon one remarkable case of a low consumption rate of coke, which was given me as obtained in furnaces having a height of 85 feet, with 27 feet boshes. Here the iron, generally grey forge, was stated to have been made with 18·38 cwts. of coke, the average over two months being 18·71 cwts., the ore (Cleveland) yielding 41·7 per cent. of No. 4 iron, and the limestone per ton of metal being 10·9 cwts.

Exp. 809. Four trials of the blast made with the electric pyrometer gave—

$$861°, 921°, 834°, 879°F. = \text{average } 873°F. (467°C.)$$

Exp. 810. Twenty-four readings of the temperature of the escaping gases afforded a mean of 318°C. (605°F.)

These numbers indicate pretty strongly that if the furnace in question is doing better duty than its neighbour, it is not because there is anything extraordinary in the quantity of heat it is receiving with the blast, nor in the unusually efficient way in which the escaping gases are surrendering their sensible heat to the incoming materials.

The gases were sampled over a period of $1\frac{3}{4}$ hours, and although this was repeated, in both cases an excessive quantity of CO_2 was apparent. I am, however, disposed to regard both sets of analyses as accidental, because the carbon in this form of combination amounted to more than the usual equivalent. Overlooking this discrepancy, it will be seen in the following estimate that the heat evolved, including that from the excess of C as CO_2, indicates a considerable deficiency, denoting an error somewhere in the figures, which error is further confirmed by the want of agreement between the oxygen, as shown by the analysis, and that in the blast and minerals.

The analyses of seven specimens gave:—

	CO_2	CO	H	N	
Exp. 811.	15·5	... 25·5	... ·9	... 58·1	
	16·1	... 25·4	... ·9	... 57·6	
	15·0	... 26·0	... nil.	... 59·0	
	15·1	... 26·8	... nil.	... 58·1	
	15·3	... 26·4	... ·1	... 58·2	
	15·0	... 25·5	... ·8	... 58·7	
	15·4	... 24·6	... ·9	... 59·1	
100 vols. ...	= 15·34	25·74	... ·52	... 58·40	
100 parts weight*	= 22·22	... 23·79	... —	... 53·99	
Carbon ...	= 6·06	... 10·19	... —	... —	= 16·25
Oxygen ...	= 16·16	... 13·60	... —	... —	= 29·76

Taking the coke at 18·75, and limestone at 10·9, we have, for heat development:—

		C in coke and lmest.
Coke used per ton of iron, 18·75; less 7½% imp. 1·4	=17·35	18·66
C, in limestone, carrying off equal weight C ...	1·31	
	16·04 × 2,400 = 38,496	
C of this CO burnt to CO_2 ...	6·73 × 5,600 = 37,688	
	76,184	

Gases, weight per ton of iron—

Total carbon, per ton of iron, in coke and limestone...	18·66
Less taken up by iron...	·60
Weight of carbon in gases	18·06

Nitrogen (16·25 : 53·99 : : 18·06 :) ...	60·00		
CO_2 ... (53·99 : 22·22 : : 60·00 :) ...	24·70	= 6·73C	+ 17·97 O
CO ... (53·99 : 23·79 : : 60·00 :) ...	26·44	= 11·33 „	+ 15·11 „
Water and hydrogen	·56	—	—
	111·70	18·06 „	33·08 „

Weight of blast—Nitrogen as above...	60·	
Oxygen with do. ...	17·97	
Moisture	·50	
		78·42 cwts.

* The calculation is based on average composition of the two sets of analyses.

Comparison of oxygen—per ton of iron, as above, ...		33·08
Oxygen in blast	17·92	
„ in moisture of blast ...	·44	
Ore	9·00	
Limestone	3·49	
		30·85
Difference, showing error		2·23

Total heat statement—

From oxidation of carbon, as before	76,184
Contributed by blast...78·42 × 467° × ·237 S.H. ...	8,676
	84,860
Less in gases ... 111·70 cwts. × 318° × ·24 S.H. ...	8,522
	76,338

Certain discrepancies appear in this estimate which I am unable to reconcile. There is too much oxygen, which indicates probably that too high a percentage of carbon has been reckoned as CO_2,which seems probable on the face of this statement. Assuming, however, that the quantity of CO_2 is correct, the number of heat units is considerably below that found upon previous occasions as being required to the ton of iron. Making allowance for the heat contained in the ironstone, the difference is not far from that represented by 2 cwt. of coke burnt to the state of CO.

Mr. B. Samuelson, M.P., has given, in a paper to the Institution of Civil Engineers,* a very comprehensive description of two furnaces he has recently erected at Newport, near Middlesbrough. In it, every particular is clearly set forth of what constitutes a smelting plant of the most modern and most efficient character, and, in justification of this praise I may add that I am not aware that any furnaces in their neighbourhood are doing better duty, and a good many, I believe, are not doing as well.

Mr. Samuelson mentions, as an exceptional result, their having made during one week a ton of iron with 18·78 cwts. of coke, but he also alludes to the calcined Cleveland stone having yielded 45·29 per cent., the average of this kind of stone, he states, being 37 to 40 per cent. Either there has been metal made, during the

* *Vide* "Minutes of Proceedings of Civil Engineers," 1871.

period in question, carried into the account belonging to previous workings, or the ironstone used has differed considerably from that character upon which my statement as to fuel consumption was based. In neither case, therefore, can the figures quoted in this paper be considered as impugning the correctness of the estimate I have formed of the *minimum* heat, and therefore the *minimum* fuel required in the process for smelting an ore affording 41 per cent. of metal.

The author, with that candour which marks the intercourse of the Cleveland ironmasters, and which I believe has greatly tended to the advancement of their common interests, gives many particulars of the work performed. The average quantity of ironstone consumed is given at 46·11 cwts. per ton of iron, equal to 43·37 per cent., which is above that usually obtained from Cleveland ironstone calcined. The average of the fuel was 20·35 cwts.

By permission, kindly granted by Mr. Samuelson, I have been allowed to examine the furnaces described in his paper.

Exp. 812. The blast, as determined by Siemens' electric pyrometer, had a temperature of 516°C. (961°F.), and the gases averaged over two hours, 305°C. (581°F.), but as this did not include the dinner hour, when it rises considerably, 320°C. (608°F.) would probably, therefore, be about the actual mean.

Exp. 813. The gases were sampled at seven different times, and contained, on the average—

$$CO_2\ 11{\cdot}7,\ CO\ 28{\cdot}3,\ H\ 1{\cdot}2,\ N\ 58{\cdot}8 = 100 \text{ vols.}$$

In this, the CO_2 is to the CO as 41·34 vols. to the 100, corresponding closely with what is the usual ratio.

Calculated upon the burden of mine carried upon a given weight of coke, and assuming it to yield 41 per cent., the consumption of fuel was 21·42 cwts. per ton of metal. Upon this occasion, the flux was used in its calcined state, so that, with raw limestone, the probable quantity of coke would have been 22 cwts.

These furnaces are 85 feet high, 28 feet across the boshes, and contain 30,000 cubic feet.* The temperature of the blast was very good, nearly 1,000°F., and, according to my opinion, their performance was excellent. Notwithstanding this, *quite as favourable results* are at this moment being obtained from one of the Clarence

* *Vide* "Gjers on Cleveland Blast Furnaces, Journal of Iron and Steel Institute, November, 1871, p. 207."

furnaces of 15,500 cubic feet, with its blast a few degrees below 900°F. If this is not conclusive evidence that the profitable limits of dimensions of furnace, and temperature of blast have been reached, and, indeed, exceeded, I do not know where we have to look for the proof. It is true, Mr. Samuelson himself states that in some other furnaces of his own, containing 16,000 cubic feet, the fuel was 15 per cent. above that of the larger ones just mentioned. This is equal to 24 to 25 cwts. per ton of iron; but inasmuch as they are only 69 feet high, instead of 80 feet like those at Clarence, it cannot from this be inferred that 16,000 cubic feet, contained in suitable dimensions, is not amply sufficient for the work, so that taking the facts as stated by Mr. Samuelson, I think I am entitled to say they confirm, to the letter, what has been advanced in these pages.

A few words, before concluding this section, in reference to the shape of the furnace, to which attention was called at the conference of the Institution of Civil Engineers, already alluded to.

No one can be more sensible than I am of the fatal effects which may arise from an improper manner of distributing the materials in charging. The first furnaces over which I had control, were open-topped and charged at one door, but this was subsequently altered so that the materials were delivered at four openings. This change produced a saving of 30 per cent. in the fuel, and an increase of above 50 per cent. in the make. The mere contraction of a couple of feet in the diameter of the throat threw a furnace, upon another occasion, from foundry to white iron, in which manner it continued to work so long as the narrowed throat was persevered in. As soon as this was abandoned, the iron became grey. The imperfect mode of distribution spoken of above may also be an accompaniment of improper shape of the furnace, or of faulty construction in the cup and cone. When the escaping gases were first utilized at the Clarence Works, a considerable derangement took place in the working of the furnaces, which was remedied by enlarging the cone, so as to spread the materials more evenly, and if the more recent observations at Consett, in respect to the larger furnace (No. 5) not being prejudicially affected by receiving its blast at too high a temperature are correct, then it must be concluded that its defective performance, when compared with No. 4 furnace at these works, is due to a want of suitability in its proportions.

I am by no means prepared to deny that up to a certain capacity, shape in a blast furnace may be very important, and I am, therefore, prepared to accept any properly authenticated statement, either that Alger's elliptical furnace or Rachette's oblong one may be very useful. It must, however, be borne in mind, that all the changes in form, just referred to as having beneficially affected the furnaces upon which they were made, were applied in instances when the duty performed was greatly below that attained in more recent times, in furnaces sufficiently large. If later improvements have enabled us to deprive the gases of as much of their sensible heat as is practicable, and at the same time to exhaust their reductive power, I for one must decline believing that either of these offices can be sensibly altered by a mere change in the shape of the vessel in which they are carried on.

SECTION XLIII.—ON THE SMELTING OF CERTAIN ORES BY MEANS OF CHARCOAL.

In the different calculations which have, hitherto, been made use of to determine various questions connected with the smelting process, the mineral treated was considered to be that of the Cleveland Hills.

Regarded as a mere question of heat absorption, I have endeavoured to show that perfection consisted in allowing the gases to escape as completely deprived of their sensible heat as the nature of circumstances permitted, and to be charged as fully with oxygen gas as is consistent with the character of the operation.

I have given, at some length, my reasons for believing that when the temperature of the gases was reduced to 330°C. (626°F.), or thereabouts, they were all but inert on calcined Cleveland ore, when to every 100 vols. of CO they contained from 40 to 45 vols of CO_2.

I have further given proof, by quoting from actual experience of the furnaces at the Clarence Works, that these two conditions

were achieved when a capacity of 12,000 or 15,000 cubic feet was reached, and when the air was heated from 480° to 500°C. (896° to 932°F.)

No doubt the reducing energy of the escaping gases may be augmented by an increase of temperature in the upper portion of the furnace, which, of course, could be effected by superheating the blast; but I have also endeavoured to demonstrate that, when this is done, a secondary action is set up, by which the CO_2 resulting from the process of reduction, aided by this additional temperature, dissolves C, and thus neutralizes the advantages derived from this means of increasing the fund of heat in the furnace. Quoting from the experience of smelters who operate upon the richer and differently constituted ores of Lancashire and Cumberland, which yield their oxygen with great rapidity to the reducing power of CO, it is needless to employ furnaces above 55 to 60 feet in height. I now propose to consider some cases where the dimensions are so small that the materials pass from the throat to the hearth of the furnace in little more than four hours, and in which the proportion of CO_2 to CO present in the gases is so large that it looks as if those laws which govern the smelting of iron from Cleveland and other ironstones of the argillaceous description, as well as the richer hæmatites of Lancashire and Cumberland, with coke, experience considerable modification where other material is reduced by means of charcoal.

If a drop of sulphuric acid is added to a solution of nitrate of barium a sulphate of this metal is precipitated, and it is usual to explain the action by stating that the affinity of sulphuric acid for barium is more powerful than that of nitric acid.

If a current of CO_2 is passed over carbon as it exists in soft coke at a given temperature, the CO_2 is decomposed and two equivalents of CO are formed. In this case, it may be said that the affinity of a molecule of C for its first equivalent of oxygen is stronger than that possessed by another carbon molecule, for the second equivalent of this gas. Other varieties of carbon, such as that in hard coke, under precisely similar circumstances, I have shown, remain unaffected, although the actual order of affinities, as between C and O, just mentioned, remains, of course, unchanged.

In like manner, when a mixture of CO and CO_2 is conducted over two varieties of Fe_2O_3 such as those described in Exps. 99 and

101, in which 100 vols. of the former and 50 vols. of the latter were brought in contact with calcined Cleveland stone, and Fe_2O_3 obtained by precipitation, the effect is very different, inasmuch as, at the same temperature and in the same time, the pure Fe_2O_3 lost four times as much of its oxygen as the iron oxide in the molecular form in which it exists in Cleveland ore.

This difference of behaviour, of course, cannot be set down to the reducing gas, CO, having a more powerful affinity for the oxygen in one form of the same substance (Fe_2O_3) than in another.

In comparing the treatment of the same kind of ore in furnaces of different capacities, the value of *time* in the conflict of opposing forces which are at work in a blast furnace has been made sufficiently apparent. In such cases, the periods of time dealt with had a very appreciable duration, but it is probable, indeed certain, that where they do not admit of actual admeasurement, owing to the rapidity of the exchange of elements, it is *time*, all the same, we must look to for an explanation of phenomena which appear, at first sight, contradictory in their nature.

If, for example, at a given depth in a blast furnace, where a certain temperature prevails, no CO_2 is to be found, and in another, using a different ore but other circumstances being equal, a considerable quantity of this acid is always present, without interfering with the process of reduction, it may be inferred, in the first case, that the rapidity of CO_2 to part with O to C is greater than that with which CO absorbs O from the ore; and, in the latter, the reverse of this action is what happens.

This reversed action may also take place with the same ore, but, when the forms of carbon are different, as we have seen, according to whether the coke is hard or soft. When hard, the action of CO_2 on it is so slow, that deoxidation of the ore is much more rapid than the action $CO_2 + C = 2\ CO$. On the other hand, when the coke is soft, the carbonic acid dissolves C so rapidly that the quantity arriving at the hearth for combustion, is so much diminished as to augment very notably the consumption of fuel.

The preceding remarks are suggested by the analyses contained in a paper,* by Professor Tunner, previously referred to, which contains the following facts.

* Theorie des Hauts Fourneaux. Revue Universelle, 1860, 1. Sem. p. 464.

Composition of gases of the Wrbna blast furnace, working with calcined Eisenerz ore (spathose, or brown hæmatite) and charcoal:

Distance from throat.	By volume. N	By volume. CO_2	By volume. CO	By weight. N	By weight. CO_2	By weight. CO
About 10 ft. 9 in.	70·50	16·39	13·11	63·50	23·56	12·94
„ 17 6	71·36	17·80	10·89	60·52	24·86	14·62
„ 22 6	68·81	9·60	21·59	64·90	14·26	20·84
„ 27 8	66·66	2·68	30·66	65·65	4·15	23·20
„ 34 6	66·34	11·60	22·06	62·25	17·07	20·70

Volumetrically, the CO_2 to 100 vols. of CO is as follows:—

	CO_2	By weight.	Temperature.
At depth of 10 ft. 9 in.	125 vols.	182	558°C
„ 17 6	163 „	170	Between 580 and 840
„ 22 6	44 „	68	„ 840 „ 910
„ 27 8	8 „	18	950
„ 34 6	52 „	82	1450

The Wrbna furnace is 36 feet high, with a capacity of only 1,200 cubic feet, and makes, notwithstanding, 140 tons of iron per week, it therefore presents interesting matter of enquiry, particularly, when it is remembered, 14 cwts. of charcoal, per ton of iron, burnt with air at 200°C. (392F.) was the quantity of fuel consumed.

Wishing, in the first instance, to be assured that the analyses given above really represented an average of the composition of the gases, I suggested to Professor Tunner the desirability of making a second series. This was kindly done by my excellent friend, but, upon this occasion, the blast had been raised to 400°C. (752°F.) The specimens were collected by means of enamelled pipes, so as to avoid any action by passing over metallic iron, the material formerly used for obtaining the gas. The charcoal now was reduced to 13·20 cwts. per ton of metal.

Composition of gases at Wrbna furnace, 1871, by weight:—

	N	H, &c.	CO_2	CO		100 CO $=CO_2$
Escaping gases	54·46	·67	21·47	23·40	=100	92
„ 2nd trial	54·90	·39	20·90	23·81	=100	88
18 feet from throat	53·38	1·01	19·79	25·82	=100	76
25½ „ „	54·57	·27	20·29	24·87	=100	81
28 „ „	55·00	·24	18·50	26·26	=100	70
32 „ „	54·34	·20	18·14	27·32	=100	66
34 „ 6 in. „	57·35	·11	4·61	37·93	=100	12

It will be observed there is a considerable variation between the figures contained in the first and the repeated series of analyses, but whether this is due to the difference in the temperature of the blast, or to some of those irregularities already spoken of, I am unable to say. One thing, however, is certain, viz., that there is in both sets an excessive amount of CO_2 in relation to the CO when compared with the gases emitted in smelting Cleveland stone.

Now, the explanation I would give of this large quantity being present is, that when the reducing agent CO is rushing through the furnace, it takes up O and passes into the condition of CO_2 more rapidly than the resulting CO_2 takes up C, and it is the amount of the difference between these two reactions that constitutes the difference between smelting the calcined ore of Eisenerz with charcoal, and that of Cleveland smelted with coke.

The difference in question may arise from one of two causes, either charcoal must be much less easily attacked by CO_2 than coke, or the Eisenerz ore is much more susceptible of reduction than that of Cleveland, or it may be a combination of both these differences that constitutes the change of condition. Experiments were undertaken to determine which of these two causes produced the remarkable deviation in question.

The soft and porous nature of charcoal rendered it extremely unlikely that CO_2 could act less energetically on it than on hard coke. This, however, was subject for experiment, and not opinion.

Exp. 814. 18 grains of well burnt silvery coke were placed in a combustion tube, heated to a good red, in a Hoffman's double gas furnace, and 800 c.c. of dried CO_2 were passed over it in 30 minutes.

The resulting gas consisted of—

CO_2	94·56	vols.
CO	5·44	„
		100 vols.

showing the action was very slight.

Exp. 815. Made to compare the action of soft coke on CO_2 with that of hard coke and that of charcoal. Alongside of the tube used in previous experiment, a similar quantity of a very open and soft specimen of the coke was exposed under similar circumstances as to temperature, time, and quantity of CO_2 passed over it.

The issuing gas was composed of—

CO_2	69·81
CO	30·19
	—— 100 vols.

In this case the action was very rapid, nearly one-third of the resulting gases being CO.

To satisfy myself that this more rapid decomposition was not due to a large quantity of H being present in the coke, the two specimens were analyzed—the sulphur being disregarded.

	Exp. 816. Hard Coke.	Exp. 817. Soft Coke.
Carbon	93·49	84·83
Hydrogen... ...	·37	·92
Oxygen, difference	nil.	1·47
Ash	6·67	12·78
	100·53	100·00

Exp. 818. The tube was now filled with charcoal, in pieces as nearly as possible the same size as the coke, and dry CO_2 passed over it at the same rate as in Exps. 814 and 815. Owing to the lightness of the charcoal it only weighed 6 grains. 800 c.c. of the CO_2 passed over in 30 minutes at a good red heat.

Issuing gas contained—

CO_2	35·2
CO	64·8
	—— 100 vols.

Exp. 819. A second experiment, with a somewhat quicker current of CO_2, gave—

CO_2	57·14
CO	42·86
	—— 100 vols.

These experiments prove incontestably that the advantage manifested in smelting the Eisenerz ore is not in any way due to any superior power charcoal possesses in resisting the action of CO_2.

The next stage was to examine and compare the readiness with which the ores used in this Austrian furnace yielded their oxygen when exposed to the reducing gas. They consisted of spathose ore

as Fe CO_3, and of the same bed of mineral in various states of alteration, caused by atmospheric influence. They were designated:—

No. 1. Spathose unaltered ore.
„ 2. Spathose ore slightly oxidized, first stage.
„ 3. „ changed into "Braunerz" (br. hæmatite).
„ 4. „ „ "Brauner Glaskopf."
„ 5. „ „ "Plauerz."

Specimens of these, calcined, and of thoroughly roasted Cleveland stone were exposed simultaneously in the lead bath arrangement, with the usual precautions, to a current of CO for 8 hours at a temperature of about 400°C. (752°F.)—zinc barely softened.

	Exp. 820. No. 1.	Exp. 821. No. 2.	Exp. 822. No. 3.	Exp. 823. No. 4.	Exp. 824. No. 5.	Exp. 825. Cleve.
Original O removed %	77·73	91·31	29·5	42·92	17·18	41·91
C deposited per 100 Fe	1·00	2·10	7·41	18·01	4·71	2·32

The above experiments were repeated—

	Exp. 826. No. 1.	Exp. 827. No. 2.	Exp. 828. No. 3.	Exp. 829. No. 4.	Exp. 830. No. 5.	Exp. 831. Cleve.
Original O removed	65·3	74·1	30·3	40·8	17·	39·3
C deposited per 100 Fe	1·55	2·0	7·2	18·5	4·7	2·8

The next series was tried also during 8 hours, at same temperature, to oxalic acid gas (equal vols. CO and CO_2).

	Exp. 832. No. 1.	Exp. 833. No. 2.	Exp. 834. No. 3.	Exp. 835. No. 4.	Exp. 836. No. 5.	Exp. 837. Cleve.
Original O removed %	29·2	31·2	12·89	9.71	6·48	9·35
Carbon deposited	nil.	nil.	nil.	nil.	nil.	nil.

In every case it will be seen that Nos. 1 and 2 (as, I believe, from the chief bulk of the ore smelted) lost oxygen very much more rapidly than Cleveland stone, and when this loss of O was not greater, or was less in the case of the altered ore than in Cleveland stone, the carbon deposition was much larger in the Austrian ore.

The circumstance, however, which bears more directly upon the greater ease with which the Eisenerz ore is smelted is the great difference which exists when the CO_2 has greatly weakened the reducing power of the CO. Thus, while Nos. 1 and 2 of the

spathose ore have lost something like half the oxygen in oxalic acid gas (equal vols. CO and CO_2) which they did in pure CO, the Cleveland stone, under the same circumstances, has had its loss of oxygen reduced to one-fourth.

In order to compare the behaviour of calcined Cleveland stone with calcined spathose ore, under circumstances more analogous to those which obtain in the blast furnace, the former was mixed with pounded coke, and the latter with pounded charcoal. The two mixtures were placed in separate combustion tubes, and heated simultaneously to a good red heat in the double Hoffman's gas furnace, during which a stream of oxalic acid gas was passed over them.

Exp. 838. Of calcined Austrian spathose ore, containing 58·4 per cent. of Fe, 20 grains were mixed with 7 of charcoal. Passed over it 8 litres of a mixture of CO and CO_2. Time of experiment, 45 minutes.

Loss in weight of charcoal	...	1·679 grains.
„ of oxygen by ore		1·541 „
The charcoal has lost	23·9 %	of its carbon.
„ ore „	31· %	„ original oxygen.

Exp. 839. 20 grns. of calcined Cleveland stone were mixed with 8 grns. of powdered hard coke, and the same quantity of oxalic acid gas was passed over it, as in Exp. 838, also during 45 minutes.

Loss of weight of coke ...	...	·358 grains.
„ „ O by ore	...	·611 „
The coke lost of its carbon	...	4·9 %
„ ore „ original O	...	17·4 „

These two experiments may be taken as confirming what has already been advanced respecting the relative action of CO_2 on charcoal and on coke, and the greater readiness with which the Austrian ore, compared with that of Cleveland, loses its oxygen.

In these two experiments, the gas used was obtained from oxalic acid, but, as it was stored over water, a portion of the CO_2 was absorbed, reducing it to a mixture of about 60 vols. CO to 40 CO_2. These experiments were repeated, and the composition of the current of gas ascertained before and after it passed over the mixtures of ore with coke and charcoal.

Exp. 840. 20 grains calcined Austrian spathose ore, mixed with 7 grains of powdered charcoal, exposed for 45 minutes, at a bright red heat, to a current of 64 vols. CO and 36 CO_2. About 3 litres of the mixed gases were passed over in the time.

The charcoal lost	...	1·540 grains equal to	22 per cent. of its C
„ ore „	...	2·316 „ „	46·2 per cent. original O

Three trials of the issuing gas gave the following results :—

	CO		CO_2	
100 vols. =	35·7	...	64·3	taken 10 minutes after commencing
„ „	70·7	...	29·3	„ 30 „ „ „
„ „	73·	...	27·	„ 50 „ „ „

Exp. 841. 20 grains calcined Cleveland ore, mixed with 8 grains powdered hard coke, were treated in a similar manner to that described in the last experiment, with the exception that the gas contained 60 vols. CO and 40 CO_2.

The coke lost	·405 grains, equal to	5·	% of its C.
„ ore	„ ·781 „ „	22·3	„ original O.

The issuing gases were composed of—

	CO		CO_2	
100 vols. = ...	36·	...	64·	taken 10 min. after commencing.
„ „ ...	56·7	...	43·3	„ 30 „ „
„ „ ...	55·	...	45·	„ 50 „ „

As regards the issuing gases, in both cases the first trial may be disregarded from the apparatus not being fully heated. These being eliminated, we have 100 vols. of the issuing gases containing as follows :—

From spathose ore and charcoal	71·8 vols. CO	...	28·2 vols. CO_2
„ calcd. Cleveland and coke	55·8 „ CO	...	44·2 „ CO_2

We have, therefore, it will be seen, firstly, the Austrian ore losing its O much more readily than the English; secondly, doing so to a much greater extent in an atmosphere richer in CO_2 (*vide* Exps. 833 and 837); and thirdly, the gases have their reducing power constantly reinforced by the ready manner in which the charcoal absorbs O from the CO_2, producing fresh supplies of CO, which is ready to perform the office of deoxidation on fresh quantities of ore.

The furnace of Eisenerz contains only about 1,200 cubic feet, or

40 cubic metres, and, taking its make at 140 tons per week, and using 14 cwts. of charcoal per ton (no limestone being needed), its gases per ton will be about 67 cwts., or 2,600 cubic metres. Thus, per minute, there will rush up (at 760 m.m. and 0 c.) about 30 cubic metres of gases for 1,000 cubic feet of furnace capacity, which is (Section VI.) near three times that rising through one of the larger Cleveland furnaces.

In like manner the current of solid materials passing through each 1,000 cubic feet of furnace space per minute is ·62 cwts., which is four times the speed of that common in the vicinity of Middlesbrough.

The manner, then, in which I would account for the marked difference between the composition of the gases in a furnace smelting Cleveland ore and Austrian spathose, the former using coke and the latter charcoal, is as follows:—The stream of CO flowing up the Eisenerz furnace encounters the ore it has to deoxidize, as well as C, ready to reduce the CO_2 generated by reduction, back again to CO. The readiness, however, with which the oxygen is given up by the ore exceeds that with which the carbon of the charcoal is oxidized at the expense of the CO_2. In the coke furnace, the fuel, it is true, is much less easily acted upon by CO_2 than is the case with charcoal, but on the other hand, the Cleveland stone is so much more difficult of reduction as to produce a state of equilibrium in which the relation of CO_2 to CO is much less than that which obtains in the charcoal furnace under examination.

It may possibly be suspected that the cause of charcoal being able to perform its duty so efficiently in the Eisenerz furnace, *i.e.*, with so small a quantity, is due to its greater calorific power. This, however, is not so to any extent, for the calories evolved by the combustion of one of charcoal is, according to Andrews, 7,900, and according to Favre and Silberman, 8,080. In my estimates I have taken carbon as it exists in coke at 8,000, the mean of the value assigned to it by the same authorities, which gives about 7,600 for the coke itself.

I have endeavoured to prove that charcoal possesses no superiority over coke, in a heat-producing point of view, by the usual plan pursued in estimating the heat absorbed in producing a ton of crude iron. The following figures contain the particulars of an estimate of heat development in the Wrbna furnace, according to the analysis last given :—

CO_2 ...	... 21·18	=	C 5·77	+	O 15·41
CO ...	... 23·60	=	C 10·12	+	O 13·48
H &c. ...	... ·53		—		—
N ...	... 54·69		—		—
Weight ...	100·00		15·89		28·89

Carbon in gases per ton of iron—

Charcoal used, 13·2 cwts. less 15· per cent. imp. = C ...	11·22
No limestone used	—
	11·22
Less C dissolved in iron	·60
	10·62

Weight of gases per ton of iron—

				Carbon.	Oxygen.
Nitrogen ...	(15·89 : 54·69 : : 10·62) ...	36·55			
Carb. acid ...	(54·69 : 21·18 : : 36·55) ...	14·15	=	3·86 ...	10·29
Carb. oxide	(54·69 : 23·60 : : 36·55) ...	15·77	=	6·76 ...	9·01
Hydrogen, &c.	... ...	·35		10·62 ...	19·30
		66·82			

Comparison of O per ton of iron with that due from various sources:—

Brought in with 36·55 N of blast... ...	10·92	
„ moisture in blast, say ...	·30	
„ ironstone*	8·14 ...	19·36
Difference, experimental error ...		0·6

Heat development...3·86 cwts. C to CO_2 × 8,000 =	30,880	calories.
„ ...9·34 „ C to CO × 2,400 =	22,416	„
Total cwts. charcoal 13·20 „	53,296	„
Heat in blast ... 47·8 cwts. × 400°C. × ·237 sp. heat	4,531	„
Total cwt. calories per ton of iron ...	57,827	„

Now, according to the data formerly used (Section XXVIII.) in calculating the heat absorption which takes place during the

* In Cleveland stone, this was taken at 9 cwts. due to P_2O_5, SO_3, &c. decomposed.

production of a ton of iron, it may be assumed that the purer metal of Eisenerz requires, in round numbers, for—

Evaporation of water in fuel	300	
Reduction and carbon impregnation ...	34,600	
Decomposition of H_2O in blast	1,500	
„ of $Si\,O_2$, &c.	1,000	
Fusion of iron	6,600	
„ 12 cwts. slag	6,600	
Transmission through walls	2,000	
Tuyere water	1,000	
Leaving for sensible heat in gases ...	4,227	
		57,827

The fact that in the case under examination there is no $Ca\,CO_3$ to decompose, less SiO_2 and other impurities reduced, and a much smaller weight of slag to meet, renders, of course, a small quantity of heat necessary than is required in smelting Cleveland iron. This is further diminished by the large make in a furnace of such inconsiderable dimensions as that at Eisenerz. The table of absorption contains numbers of a somewhat arbitrary nature, but I believe they are not wide of the truth, and so far it is satisfactory that they confirm the general conclusions of an estimate based on so small a consumption of fuel as 13·2 cwts., for under no circumstances is it likely that any error could exceed that represented by another cwt. of charcoal. At the same time, it must be remarked that it is not the unusually low quantity of fuel which is the especial subject of comment at the present moment, but the large proportion of CO_2, in which the ore, under consideration, is reduced. The small consumption of combustible is due, in a great measure, to the very small quantity of slag formed, fully a ton less than that which accompanies the smelting of Cleveland stone, and the absence of limestone as a flux. The difference in the quantity of fuel, from these two causes, will probably not be short of 6 cwt. to the ton of iron, so that the production of a ton of Cleveland metal, of low forge quality, with 19·20 cwts. of coke, would be about the same as a ton of a similar description of iron, made at Eisenerz, with 13·20 cwts. of charcoal.

It will be perceived that the peculiar property of the fuel, charcoal, is apparent in the analysis of the gases, because, although the deoxidation of the ore is so rapid that it outruns the oxidation

of C by CO_2, this latter action, nevertheless, goes on to a very considerable extent, as is evidenced by the fact that, whereas 6·58 cwts. of C should appear as CO_2 in the gases, per ton of iron, as due to the deoxidation and carbon impregnation of Fe_2O_3 by CO, 3·86 cwts. only are to be found in this form of combination.

I may observe, that it is possible, when the ore passes so rapidly down to the lower and more highly-heated part of the furnace, either by the charcoal itself, or by means of deposited carbon, reduction may take place under circumstances in which CO, and not CO_2 are the products of the action.

When it is considered that the fuel employed in the vicinity of the Tees is so much less easily attacked by CO_2, it might be supposed that more rapid driving of the furnaces might possibly be attended with a saving of fuel, by means of which CO_2, being formed lower down the furnace, the heat from its generation would, from having to pass through a higher column of the contents of the furnace, be more easily intercepted. The slowness, however, with which the Cleveland stone parts with its O probably prevents this and, as a matter of actual practice, we have seen in the 6,000 feet furnaces, when the solids descend and the gases ascend more quickly than in furnaces double their size, the consumption of fuel is fully 25 per cent. above what it is in those of the larger capacity.

In the manufacture of forge iron in these Styrian and Carinthian furnaces, the consumption of charcoal, until the subject is properly examined, may seem unaccountably low. Thus, from returns I possess, extending over some months, I gather the following particulars:—

Work.		Cubic Feet.	Temp. Blast.	Weekly Make.		Charcoal ℔ Ton. cwts.
Lölling,	3 furnaces	...1,379	150°C. (302°F.)	111 tons	No. 4.	13·43
Freibach,	1 „	...1,329	120°C. (248°F.)	140	„	12·14
Heft,	1 „	...1,580	170°C. (338°F.)	132	mottled	15·54
Eberstein,	1 „	...1,379	100°C. (212°F.)	97	„	15·58

I may add, however, that in other parts of the Austrian empire, I have had 21 cwts. of charcoal given me as being consumed for white iron, and as much as 31 cwts. for Bessemer, using an ore yielding 47 per cent., but in these latter cases 5 to 6 cwts. of limestone was used, whereas at the works already mentioned scarcely any flux was needed.

In connection with the greater or less consumption of combustible, German writers on iron smelting make use of the term "strengflüssig" and "leichtflüssig." If these words have to be taken in their literal sense of comparative susceptibility to fusion, their use, in my opinion, may lead to error. There are, no doubt, some differences in the melting points of different kinds of iron and slag, but these, I apprehend, are trifling and cannot account for the marked alterations, just spoken of, in the quantity of fuel required for mere liquefaction. The actual cause of the lesser quantity of consumption of combustible in small furnaces, I have conceived and described as being due to difference in susceptibility of reduction, and not of fusion.

SECTION XLIV.—SUPPLEMENTARY REMARKS ON CARBON IMPREGNATION BY DISSOCIATION OF CARBONIC OXIDE.

In Sections XI., XII., and XIII., the dissociation of carbonic oxide in its pure form, also when mixed with carbonic acid, and as it occurs in the blast furnace, was fully described. The two following sections contained enquiries into the changes experienced by metallic iron, and by an iron oxide, which have served to split up the CO, as well as an investigation into the nature of the alteration experienced by the carbonic oxide itself.

As regards the gas, there was no doubt, in addition to the precipitated carbon, a formation of CO_2, but it was also proved that in the case of metallic iron being used, there was a slight oxidation of the metal. It was considered that Fe itself was capable of dissociating the carbon oxide, and that when Fe_2O_3 was employed, there resulted, provided the action had been continued long enough, a mixture of

Metallic iron,
Unknown oxide of iron ($Fe_x\ O_y$), and
Carbon.

Thus while, according to the experiments detailed in the abovementioned sections, metallic iron was capable of effecting the separation of carbon from carbonic oxide, it did not appear that the

presence of Fe, in its metallic condition, was absolutely indispensable for the dissociation of CO.

The delicacy of the experiment required to prove this was sufficiently explained when describing the modes of research employed. I do not think that the correctness of my conclusions, or the reverse, on the precise nature of the changes in question, affect any of the arguments made use of in following the progress of the smelting process itself. In a scientific point of view, however, they are full of interest, and I am therefore well satisfied that my distinguished friends M.M. Grüner and St. Claire Deville, of Paris, have deemed the subject deserving of their attention.

The details of the investigations of these able chemists have not yet been published, but a private letter to myself, dated 20th Dec., 1871, from M. Grüner, contains some account of their labours. The following is a translation of what relates to the matter in question:—

"I have communicated to our Academy of Sciences an article on the reactions of CO on iron and on ores of iron, quoting you, of course, as the author of this interesting discovery. The article is a *resumé* of my experiments, performed during last year between the months of May and the end of November, and extracted from it are my conclusions, which appeared in the 'Comptes Rendus de l'Academie des Sciences de Paris.' The article itself will not be published until later, because the Academy has nominated a commission to report on my experiments, at the head of which is M. St. Claire Deville. This chemist has already verified the correctness of my conclusions, which I give below, observing, in the first place, that I do not agree with you on every point.

"1st, Carbonic oxide, *perfectly pure*, does not attack iron between 300° and 500°*; if there is a deposition of carbon, it is always caused by the presence of a small quantity of oxygen, either in the iron, or in the apparatus, or by the gas containing a little CO_2.

"2nd, On the other hand, as soon as the iron is slightly oxidized (and you know that perfectly deoxidized iron is scarcely to be obtained), or as soon as CO is mixed with traces of CO_2, or of O, carbon commences to be deposited by the action $2\ CO = C + CO_2$.

"3rd, But this decomposition of CO is never spontaneous; the

* It is presumed centigrade degrees are meant.

carbon which is deposited contains always *iron* and magnetic oxide. The carbon deposited, either on iron, by the mixture of CO and a little CO_2, or on the ore, by a prolonged action of CO, is *wholly attracted by a magnetised bar;* it is not pure carbon, but a ferruginous carbon containing 6 or 7 per cent. of iron.

"4th, It is equally certain that the deposition of this ferruginous carbon does not commence until the iron is *partially reduced to the metallic state.* No doubt, in operating on *pieces* of ore, the interior may remain intact; but outside of this there is a metallic pellicle, and carbon is deposited as soon as there is a faint pellicle of iron on the surface of the pieces.

"5th, The ferruginous carbon contains, *at the same time,* some metallic iron and some magnetic oxide, which is reproduced continuously in presence of oxygen or of CO_2. I account for the phenomenon by supposing that the ordinary oxide once reduced to the state of protoxide and suboxide—

we have $3\ FeO + CO = Fe^3O^4 + C.$,

and then $Fe_3O_4 + CO = 3\ FeO + CO_2$

and so on indefinitely, *provided there is a little* CO_2 *mixed with the* CO; without this, in time the FeO is completely reduced, and no more Fe_3O_4 appears. Carbon deposition then is arrested.

"We may equally have in the case of a suboxide—

$$3\ Fe^2O + 5\ CO = 2\ (Fe^3O^4) + 5\ C.$$

(the 5 C being combined with a little iron)

and then $2\ Fe^3O^4 + 5\ CO = 3\ Fe^2O + 5\ CO^2$.

As the suboxide, however, is hypothetical, the first reaction appears to me the more likely of the two.

"6th, Lastly, as regards the blast furnace, I am scarcely prepared to admit that the carbon thus precipitated is that which is found in the pig iron. As soon as the mixture of ore partially reduced arrives in an incandescent portion of the furnace, the carbon is burnt by the oxygen still remaining in the ore.

"In other respects, I entirely agree with your views on this decomposition of CO.

"I think, also, with you, that furnaces may be built needlessly high. It is evident that, beyond a certain height, the gases are not further cooled on account of the heat *developed* by the reduction of 2 CO into $C + CO_2$."

I do not feel myself warranted in calling in question statements,

of a purely scientific nature, made under such high authority as that of the names quoted above. In respect to the action of CO on calcined Cleveland stone, I would, however, remark, in connection with the fourth of the above-mentioned conclusions, that, so far from the surface of the ore exhibiting to the eye any trace of a faint pellicle of metallic iron, when the interior was blackened by the exposure to the gas of a blast furnace, there was generally, on breaking the mass, a thin covering of apparently red $Fe_2 O_3$ found coating the exterior. I have imagined this might be due to an accumulation of CO_2, produced by the dissociation of the CO exercising an oxidizing influence on the outside of the fragments of ironstone.

To No. 6 of the conclusions, relating to deposited carbon being the source of this element in pig iron, I am also unable to state positively that my surmise on this head contains the true explanation of its origin. I am, however, not prepared to admit the soundness of M. Grüner's argument, which consists in supposing that all the deposited carbon, in ore partially reduced, must, or can be burnt by the oxygen remaining in the ore.

Now, if all the O, combined with 100 parts of iron, had to be removed by C as CO, which form of action would require the largest quantity of carbon, about 32 parts of this element would suffice for the operation. But I have shown in Exps. 278, 279, 280, and 281, that a current of CO removed 43·2, 35·5, 58·8, and 56·6 per cent. of the original O from Cleveland stone, and deposited per 100 of Fe, 125·6, 195·3, 358·5, and 140·6, respectively of carbon. It is clear, under such a state of things, the ore would be powerless, by means of the O it contains, to rid itself of such a superabundance of carbon.

If we turn to the furnace itself, we have this view entirely confirmed, *i.e.*, the deposited carbon is seen, as I have already upon more occasions than one pointed out, in enormous quantities.

If then, the assertion, that this form of carbon is the source of the element, is a mere inference on my part, I think it not an unreasonable one, viz., that iron, in the reduced ore, intimately impregnated with carbon, will more likely, at the moment of fusion, unite with a substance by which it is so thoroughly incorporated, than be melted first, and derive its C from the large fragments of coke over which it runs.

There is a fact in connection with the smelting of iron, which has, to myself, hitherto been somewhat difficult of explanation, and which confirms, I think, the opinion I have expressed on the existence of this large quantity of deposited carbon in the lower part of the blast furnace. If a fragment of fire-brick of the same quality as that which constitutes the hearth is so placed that a current of hot liquid slag flows over it, as soon as the brick acquires the temperature of the slag, or before, it is rapidly corroded, and speedily disappears. Now, what seems somewhat of a mystery, is the power of the masonry inside the furnace of withstanding, for several years, a current of nearly 100 tons a-day of this corroding slag.

I imagine this vast production of deposited carbon affords a solution to the mystery. In the lower part of the furnace it becomes, I think, incorporated into a kind of concrete, with slag, &c., and thus protects the actual surface of the brickwork from the action of the liquid contents.

It is well known to every furnace superintendent that the effect of a "scouring" cinder is to clear out all accumulation of slag, &c., from the hearth, and after this is done, the masonry itself is attacked. The colour of this scouring slag indicates the presence of a considerable quantity of unreduced oxide of iron, which, being brought into intimate contact with the "carbonaceous concrete," rapidly acts on its heat-resisting element, viz., the carbon. This corroding action continues until the slag recovers its healthy tone, and all practical men, I dare say, will agree that, until the hearth regains its original condition, inferior work is to be expected from the furnace.

Whether this explanation of the resistance of a furnace to the enormous strain upon its structure is the correct one or not, I feel very confident that M. Grüner would, after a careful examination of the working of the blast furnaces in the North of England, admit that the precipitated carbon cannot be burnt by the oxygen still remaining in the ore, and, on the contrary, that it arrives in great abundance in the hearth of the furnace. Again, whether it is the identical carbon which is found in the pig iron or not, will probably remain a subject of speculation, but I think I have given sufficient reason for regarding it as the probable source of the element.

SECTION XLV.—CONCLUSION.

My labours are now brought to a close, after greatly exceeding the limits within which I expected they would be confined, and unfortunately, perhaps, they terminate without comprehending all I wish they should have embraced.

The work, in which I have been engaged, instead of being issued after all my views were matured, made its appearance while the researches upon which they were founded were in progress, and as quickly as my other engagements would permit me to devote the necessary time to the classification of my experiments. This mode of procedure has its inconveniences, which, no doubt, will be detected by those who expect in the present to find a carefully compiled and condensed exposition of the process of iron smelting. In some few instances, a slight modification of previously entertained opinions may possibly be found, dictated by more recently acquired knowledge, and in others I have preferred a repetition of ideas, published some months before, in order to secure, if possible, a clearer statement of my meaning. I know my fellow-manufacturers will excuse any shortcoming, knowing, as they do, the circumstances under which the work itself has been written, and I must hope for equal indulgence at the hands of men of science who may feel interested in its contents, and who may value it, as recording the experience of one actively engaged in the process he has attempted to expound.

Without presuming too much upon any value of personal knowledge of a manufacture, gathered up during fully 25 years of study, I may be permitted to refer, with some degree of confidence, to the abundant opportunities I have enjoyed, obviously beyond the reach of any individual of purely scientific research, of gaining information from the most distinguished iron manufacturers and metallurgists of their day. Of the importance which I myself attach to experience and assistance so obtained, sufficient evidence will be found in what I have written; but I cannot, without expressing my gratitude, take leave of those who have never withheld

any help I sought for at their hands, and which I have always endeavoured, in its proper place, to acknowledge in suitable terms.

This discharge of a duty to others would be incomplete, were I to omit making kindly mention of the assistance I have received at the hands of the manager of the Clarence Works, Mr. John Thompson. His accurate knowledge of the working of a blast furnace, acquired during a period of nearly 27 years in the service of my firm, enabled him to select the most appropriate periods for illustrating the phenomena I wished to explain, and the real interest he felt in my labours was a sufficient stimulus to induce him, upon many occasions, to bestow several consecutive hours in patiently watching and recording facts which find a place in these pages.

When I have had to examine opinions at variance with my own, I have studied to express my dissent in a manner so as to offend no one, feeling sure, at the same time, that the sole object of both sides was the honest pursuit of the truth. I will not enlarge upon the great benefit arising from personal intercourse among men engaged in the same pursuits and cultivating the same knowledge; but I may be allowed to express that which, I am sure, is the general feeling of my colleagues in the trade, that nothing, in our own time, has done more towards the useful interchange of thought among manufacturers of iron, than the establishment of the Iron and Steel Institute. For myself, personally, I cannot speak in too grateful terms of the opportunities it has been the means of affording me of extending my information in a question in which I feel so deep an interest.

Of the subject of my present labours, I have spoken as if we had reached, or almost reached, the bounds of perfection. In a sense, this may be so, but at the same time, we frequently fall far short of it, by an omission of some minor precautions connected with the proper preparation of our materials; and, in other instances, there is a disregard of those conditions, requiring only patient study to be appreciated—conditions, which cannot be neglected without entailing certain loss.

The near approach to perfection, however, to which I have alluded, is strictly confined to the production of our pig iron with a minimum quantity of materials, as we at present receive them.

I have, in Section XLI., endeavoured to lay down the grounds

which impose a theoretical limit upon the reduction of fuel consumed in the manufacture of pig iron, and I have further attempted to define what I conceive this limit to be. This was founded upon a careful examination of the chemical properties of the agents employed in the smelting process, supplemented by many experiments and observations on the blast furnace itself. There exist, as I have explained, so many causes which interfere with the calculations made use of, that I feel it necessary to remark that it must not be understood that I draw a rigid line which cannot, under any circumstances, be departed from. More careful attention to the quality of our fuel, to the condition of our ironstone and flux, in the directions I have pointed out, may enable us possibly to effect *a little* further saving in the coke required in the operation. The rigid line in question, therefore, must not be considered as one which indicates within a few pounds the minimum of fuel, but it is one which is defined by the existence of physical laws, not sufficiently appreciated, I apprehend, by those who believe that larger capacity of the furnace, alteration in its form, or a greater intensity in the temperature of the blast, can effect savings rendered impossible by natural causes.

Whatever may be said in praise of the progress made in the smelting process itself during the last fifty years, all improvement may be said to be restricted to two objects, viz., increasing the make of a furnace, and decreasing the consumption of fuel. In one most important question, little or no progress whatever has been made—that of improving the quality of the product. The ore goes in at the top, and, consistently with the furtherance of the two objects just mentioned, we receive at the bottom whatever the furnace chooses to give us, without a thought, generally speaking, being bestowed on the possibility of intercepting any of the impurities on the way ; indeed, it is only within recent years that an ironmaster dreamt of connecting any inferiority in his make with the presence of any distinct impurity in the metal, iron from one ore being spoken of as if it were almost a distinct variety of one and the same substance.

It is true, the demands of commerce, hitherto, have given little encouragement towards incurring any great outlay in the suggested direction. The very cheapness of iron has been the means of introducing its use in a thousand ways to which high price would

have shut the door, and when a better article for higher class work was required, it was easier and less expensive to go at once to better class iron, than engage in costly experiments for the purpose of freeing the cheaper article of its imperfections.

Such was the state of things, a few years ago, when the cost of producing a ton of pig iron, free from phosporus, probably did not exceed by 10s. that of Cleveland, with its 1 or 1½ per cent. of this element.

The introduction of Bessemer steel for railway bars, the necessity of constructing our locomotives and iron steamers, of great strength, combined with great lightness, have changed all this. Steel is now a form in which iron will be greatly sought after, and in such anxious request is pig iron, suitable for the manufacture of this material, that it has run up rapidly from about 60s., to nearly £6 per ton; being nearly double that of pig iron obtained from Cleveland stone.

The limit to the production of Bessemer pig is the want of ores free from phosphorus. The hematites of this country, under the sudden demand, have doubled in price, and speculators, of all kinds, are rushing off to Spain, where tracts of land, conceded without any payment a few months ago by the government of that country, are said now to be worth large premiums; at least, such is the impression left on the mind by a perusal of the published prospectuses of the day.

This may be correct, and so firm may be the grip that phosphorus holds on iron that breaking up the bonds that bind them together may defy the skill of our most scientific men; but it may be well to remember that the yearly make of iron from Cleveland stone alone, contains about 30,000 tons of phosphorus, worth, for agricultural purposes, were it in manure as phosphoric acid, above a quarter of a million, and that the money value difference between Cleveland and hematite iron is not short of four millions sterling, chiefly due to the presence of this £250,000 worth of phosphorus.

The Pattinson process does not leave one part of silver in 100,000 of lead; the Bessemer converter robs iron of almost every contamination except phosphorus, but nine-tenths of this ingredient is expelled by the puddling furnace. It may be difficult, but let it not be supposed there would be any surprise excited in the minds of chemists, if a simple and inexpensive process for separating iron

and phosphorus were made known to-morrow, so that only one of the latter should be found in 5,000 of the former; and now that there is such a margin to stimulate exertion, we may be sure the minds of properly qualified persons will be directed towards the solution of a question of such national importance.

ERRATA.

Vol. I., 1871, page 95.—Twenty-second line, for "840°C.," read "820°C."
,, ,, ,, 119.—Thirteenth line, for "Exp. 143 maximum," read "Exp. 143 minimum."
,, ,, ,, 136.—Exp. 236, for "200°C.," read "full red heat."
,, ,, ,, 220.—Eighth line, for "60 ft. and 76 ft.," read "$50\frac{1}{2}$ feet and 60 feet."
,, ,, ,, 308.—Sixth line, for "18·83" read "18·86 cwts."
,, ,, ,, 316.—Seventeenth line, for "24" read "·24."
,, ,, ,, 346.—Twelfth line, for "to," read "with."
Vol. II., ,, ,, 88. Sixth line, for "$2\frac{1}{2}$ feet," read "$21\frac{1}{2}$ feet."
,, ,, ,, 96.—Twenty-fifth line, for "weeks," read "days."
,, ,, ,, 297.—Seventh line, for "2·738," read "2·758."
,, ,, ,, 304.—Twenty-third line, for "occasionally," read "sometimes."
,, ,, ,, 313.—Fourth line, for "considering," read "examining."
Vol. I., 1872, ,, 18.—Twenty-eighth line, for "its treatment," read "treating this mineral."
,, ,, ,, 26.—Fourteenth line, for "detoriorate," read "deteriorate."
,, ,, ,, 27.—Fifteenth line, for "consideration," read "examination."
,, ,, ,, 31.—Third line, for "pig iron," read "the pig iron."
,, ,, ,, 32.—Second line, after word "quantity," insert "by the use of heated air."
,, ,, ,, 34.—Sixth line, for "I maintain," read "as I maintain."
,, ,, ,, 39.—Twenty-fifth line, for "19·04" read "19·08."
,, ,, ,, 40.—Second line from foot, for "20·58," read "20·62."

PROCEEDINGS

OF THE

PUDDLING COMMITTEE.

The Puddling Committee having made arrangements with Mr. J. J. Bodmer, C.E., London, and Mr. R. Lester, Tees-side Works, Middlesbrough (in the latter case by the special permission of Messrs. Hopkins, Gilkes, and Co.), to visit all works in this country where any improved appliances or arrangements for puddling were in operation, they have received from these gentlemen detailed reports of their investigations. These the Puddling Committee desire now to lay before the members.

TO THE MEMBERS OF THE PUDDLING COMMITTEE, IRON AND STEEL INSTITUTE.

Gentlemen,—In accordance with your instructions, we have visited a certain number of ironworks, at which improved appliances or arrangements for puddling are in operation, or have been tried. The three classes of improvements, or inventions, upon which we more especially have to report to you, are:—1st, mechanical rabbling; 2nd, rotary puddling; 3rd, Siemens's furnaces.

The results of *mechanical rabbling* being nearly the same at all the works which practise that system, we did not extend our visits to a greater number than was necessary to enable us to report upon the plan. Through the kind assistance of the proprietors and

managers of the respective works, we hope we have been able to gather sufficient information to make it clear what mechanical rabbling can do.

Rotary Puddling.—The report of the American Commission being now before the Institute, relating to Danks's apparatus, that patent does not enter into our part of the work. Mr. A. Spencer's rotary puddling machine we have seen in operation, at intervals, from the commencement of his experiments; but we have not witnessed his later, and improved workings of the apparatus. Our report on his process is, therefore, fragmentary; but we are informed that several of his machines will shortly be put up at the works of Messrs. T. Richardson & Sons, at West Hartlepool. Mr. B. Bayliss's patent furnace and apparatus has been tried at the Marsh Side Iron Works, Workington, but we have not been able to find that an apparatus, on Mr. Morgan's plan, has been erected anywhere.

Siemens's Furnaces.—We very much regret that we are not in a position to present a clearer, fuller, and more systematical report on this subject. Unless weighing-in to the producers extend over a couple of weeks, it is scarcely possible to ascertain the consumption of fuel with any degree of accuracy for either puddling or heating furnaces, and we are quite aware that the figures we give, relating to coal, are mere estimates. Further, in order to judge of the several difficulties which, more or less prominently, present themselves at all the works, such as differences in temperature between the in-flow side and the out-flow side of the flame in double puddling furnaces, or the conditions under which the chequer work may suffer unduly, &c., a careful watching of a furnace for some weeks would be absolutely necessary.

The questions relating to puddling being more especially what was given us to report upon, we have not been able to follow several of the patents with which we came into contact, respecting different modes of heating, or physicking, or purifying (fining) iron. Our notes on inventions and processes, such as those of Crampton, Howatson, Gorman, or of Henderson and others, we beg you will simply consider as passing remarks, named because, at one or the other place which we visited for our chief object, they had either been tried, or were still being tried.

Wherever we presented ourselves, as commissioned by you, to investigate the matters in question, we were received most kindly, and we beg to tender our thanks to all the proprietors and managers of works whom we had the honour of seeing.

(Signed) J. J. BODMER.
„ R. LESTER.

MR. JAMES WHITHAM'S DOUBLE MACHINE PUDDLING FURNACE.

The Commissioners report on the results they obtained, as follows:—

We timed one charge in detail, weighed in and out two charges, and took the rabbling time of other four charges.

	o'clock.	
Charge, 15 cwts., at	11·1	
	11·40	breaking up.
	11·45	damper down.
	11·53	mechanical rabble in, at 38 single strokes per minute.
Both sides.	11·58	hand rabbling (salt).
	11·59	mechanical rabble, at 41 strokes.
	12·5	at 74 strokes.
Both sides.	12·6	hand rabble (salt).
	12·7½	mechanical rabble.
	12·11	on the boil.
Both sides.	12·12½	hand rabble.
	12·15	mechanical rabble.
	12·17	at 48 strokes.
	12·20½	dropping; mechanical rabble out.
	12·26½	dropped.
	12·35	ready to ball.
	12·40	first ball out.
	12·51½	last ball out, 6 each side.

Total time—1 hour 50½ minutes.

For every 30 single strokes, the apparatus completed one radial movement. The iron, when dropped, is pulled over to flue with

hand rabble, then turned to bridge with the bar, and afterwards back to flue, after which it is ready for balling.

One charge, best quality 1,680 lbs., produced 1,533 lbs. (12″ bars).

Loss	...	147	,,
,, %	...	8·75	

One charge, common, ...1,680 lbs., produced 1,484 ,, (8″ bars).

Loss	...	196	,,
,, %	...	11·66	

Timed for mechanical rabbling only :—

One charge, best	29 minutes.	Average $\frac{112}{4}$ = 28 minutes.
,, ,, ...	25 ,,	
,, ,, ...	29 ,,	
,, common ...	29 ,,	

The mixtures used in the furnaces, to which mechanical rabbling is applied, are, chiefly, the following :—

	cwts.			cwts.
Kirkless Hall, forge No. 4, common	4	or	Gartsherrie, forge 3	2
Apedale ,, ,, ,,	1		Ferryhill ,, 4	5
Ferryhill ,, ,, ,,	5		West Yorkshire, white	1
Wingworth, white ,,	1		Frodingham ,, ...	2½
Frodingham, ,, ...	2		Apedale ,, ...	2½
Trent ,, ...	2			
	15			13

	cwts.			cwts.
Wingworth forge, No. 4, best ...	2	or	West Yorkshire forge, No. 4 ...	1
West Yorkshire, ,, ,, ...	2		Wingworth ,, ,, ...	2
Gartsherrie, No. 3, ,, ...	3		Kirkless Hall ,, ,, ...	4
West Yorkshire white	2		Apedale ,, ,, ...	1
Frodingham white	2		Wingworth white	2
Apedale white...	1		West Yorkshire white	1
Best refined plate	3		Best refined plate	4
	15			15

The fettling consists generally of one-third purple ore ; one-third red ore ; one-third hammer slag.

The puddlers are paid the country price per ton for common iron, and 1s. extra for best.

Messrs. Whitham have tried Mr. Crampton's system of burning the fuel in a pulverized condition. The experiments were made for about four months, from January to April, 1871.

The data, Messrs. Whitham communicated to us, are to the following effect:—Whilst their ordinary price of coal is 7s. 6d. per ton, the pulverized coal came to 16s. per ton.

The apparatus was put up under Mr. Crampton's personal superintendence, and any alterations he suggested during the time in which his process was applied to puddling, were carried out.

Sundry practical difficulties, however, presented themselves, which could not be altogether overcome. Dust was found to deposit itself all over the bottom of the furnace, and appeared to influence the quality of the iron, which, instead of showing fibre, turned out cold short. The clearing out of the combustion chamber too, from which the slag could not be made to flow off, was found objectionable, and the system was discontinued.

Figs. 1 to 4 represent a double machine puddling furnace and oscillating fire bars. The furnace is larger than an ordinary puddling furnace, but not different in construction. The rabbling apparatus is applied at the Perseverance Iron Works, (Jos. Whitham and Son), Leeds, to nine furnaces. The system has been in operation at these works for five years, and the firm report that it has given satisfactory results.

Fig. 1 is a side view or elevation; fig. 2, a plan of top; fig. 3, a plan with top removed, showing inside of furnace and grates; and fig. 4 is a transverse section of a double puddling furnace, with the machine as fixed upon it.

a^1, a^2, and a^3, are arched frames or castings bolted to the side of the furnace; a^4 and a^5 are bearers connecting the frames a^2 and a^3, over the centre of the furnace, and they support the hollow axis, b, at its upper and lower ends. To the head b^1, of the hollow axis, b, the two inclined jibs or arms b^2, b^2, are fixed. b^3, b^3 are rings or sockets at the outer end of the jibs or arms; c, c are bars passing through the sockets, b^3, b^3. A coiled spring, c^1, encircles each bar at its upper end, and rests on a cottar passing through the bar; which coiled spring is for relieving the rabble, d, when the bottom of the furnace gets out of order. The bar, c, is made in two parts, for convenience of removing the lower part out of the way of the

puddler in balling. At the lower end of the lower part is the hook, c^3, for working the rabble, d, which is made with studs on it to suit the hook. e, e are connecting rods jointed to the bars, c, c, and actuated by a crank pin on the toothed wheel, f, the axis of which is received into and turns in the hollow axis, b; g is a pinion driving the wheel, f, having an axis, g^1, carried at its upper end by the bearer, a^4, and at its lower end by another bearer, a^6; g^2 is a bevelled pinion on the axis, g^1, gearing with a similar pinion on a horizontal shaft, h, supported near one end by the bearer, a^4, and near the other end by the frame, a^1. h^1 is another bevel pinion on the outer end of the shaft, h; it gears with a pinion, i^1, on the shaft, i, which runs along horizontally at the back of the furnace, being supported by brackets, a^x, fixed to the frame, a^1; the pinion i^1, is loose on the shaft, and has a clutch formed on its bos to work into a corresponding clutch sliding in and out of gear with the pinion, i^1, when it is required to drive the pinion. h^1. By this means the bars, c, receive a swinging motion, causing them to move the rabbles across the furnace from side to side. The jibs or arms, b^2, are carried partially round, first in one direction and then in the other, by their axis, b, which receives its movement from a crank pin carried by an arm on the axis, k. A connecting rod, l, links the crank pin with the pin, b^x, on the head, b^1, of the axis, b; and the axis, k, has a worm wheel on it, which is driven by a worm, h^2, on the horizontal shaft, h. The motion of the jibs or arms, b^2, is not continuous, for the end of the connecting rod, l, which embraces the pin, b^x, is slotted, so that at the end of each vibration the connecting rod does not act to reverse the motion, until the rod has moved so far that the pin, b^x, is brought to the opposite end of the slot; and during this time the jibs or arms, b^2, are held stationary by the spring catch, m, falling into inclined recesses in the head, b^1, by which means the rabbles get three or four extra strokes, one into the jamb, and one into the neck of the furnace.

Fig. 3 shows a winged interlocking fire bar, which may be used for puddling furnaces, and for all other furnaces and boilers. The wings, when in position in the grate, are interposed between one another, by which means a larger area of air space is obtained than by the bars hitherto used, a more complete combustion of fuel is effected, and, by giving the bars a rocking or rotative motion, it

keeps them very free of clinker and slag, thereby effecting a considerable saving in the consumption of fuel and greatly reducing the labour of the men.

MR. DANKS'S PATENT REVOLVING PUDDLING FURNACE.

[The Commissioners give a full description of the furnace, furnished by Mr. S. Danks, who personally explained all the details. As a paper has been published in the JOURNAL on this subject, it is not thought necessary to print the report of the Commissioners on this furnace. The following remarks by Mr. Lester, on some experiments made by him, are however, inserted here.]

Experiment made by Mr. Lester, with the permission of Messrs. Hopkins, Gilkes, & Co. Analysis made by Mr. Proctor, Middlesbrough. August, 1871.

The experiment was made for the purpose of ascertaining the effect of oxide of iron upon molten iron, simply by causing the oxide to rise through the bath of iron, especially in reference to the elimination of phosphorus.

A charge of No. 4 forge, Cleveland pig, was melted in a cupola, A puddling furnace was kept ready. About 2 to 3 cwts. of hammer slag (shot cinder) was thrown over the bottom of the puddling furnace, and about 4 cwts. of molten iron from the cupola was run in, over the cinder. The heat was then raised, and the charge was left untouched, until the cinder had risen to the surface of the iron.

Sample C of iron, and sample H of cinder, were then taken. The damper was then closed, and the puddler commenced to work as the iron was found to come on the boil. The moment when the iron commenced to show grain, sample D of iron was taken. On dropping, sample E of iron, and sample I of cinder were taken.

	A	B	C	D	E	F	G	H	I
	Pig before going into cupola.	Scrap from iron after melting in cupola.	Iron at time when cinder was taken off.	Iron when forming into grain.	Iron taken on dropping.	Puddled bar.	Cinder before charging.	Cinder after it passed through bath of iron.	Cinder taken when iron was dropping.
Combined carbon	0·75	1·20	1·30	1·85	1·15	...	...	...	...
Carbon	...	...	...	...	0·20	0·05	...	...	...
Graphite	2·40	2·	0·70	0·05	...	...	...	...	...
Silicon	1·48	1·36	0·07	0·04	0·04	0·07	...	...	...
Sulphur	0·19	0·17	0·06	0·02	trace	0·04	...	...	...
Phosphorus	1·39	1·55	0·32	0·20	0·33	0·30	2·69	3·28	3·37
Manganese	0·36	*0·57	trace	trace	...	...	...	...	...
Iron, by difference...	93·43	93·15	97·55	97·84	98·28	99·54	...	...	...
Phosphoric acid	...	...	...	...	...	...	6·17	7·51	7·73

* A little iron escaped into manganese.

Experiment made by Mr. Richard Lester, the lining consisting of a mixture of oxide of iron and lime, in an ordinary puddling furnace, at Messrs. Hopkins, Gilkes, & Co.'s, Tees-side Iron Works, Middlesbrough-on-Tees.

A newly-built furnace was employed, so as to admit of the mixture being applied next the plates round the frame of the hearth. The mixture was four inches thick, and was composed of one part of lime to two parts (by bulk) of oxide of iron, or what is termed, in practice, "best tap," *i.e.*, cinder from the balling furnace in the rail mill. The furnace was heated to its highest pitch, and firing was continued three hours without any perceptible diminution, of what is called by Mr. Danks, the "initial" lining. Scrap iron was then put into the furnace, and a "bottom" having been made to work upon, it was fettled in the ordinary way. The puddler worked as usual for the week, and when Mr. Lester examined this lining, it was found intact, excepting where the mixture came in contact with the bricks; the cementation of the oxide of iron and the lime, with the usual fettling, appearing to impregnate about half an inch. The remaining part resisted any further heat, and only when by continuance of working, the solidified portion of the "initial" lining worked without the ordinary fettling, did it give way. Any amount of heat, says the operator, is resisted, but when it comes in contact with the cinder of the iron whilst working, the same effect is not apparent, but still it is much better than ordinary fettling. The above lining remained in the furnace a fortnight, and at the end of the time was like dust under the fettling, there not being enough lime to make it adhesive. Afterwards, two parts of lime to three of oxide of iron were put in, and operated upon for a month in the same way, from which some samples were taken. The furnace in which the experiments were made was specially erected for attaining high heats, and in the above-mentioned trials the heat produced was so great that the door-hole was melted away. Mr. Lester does not hesitate to say that no other description of fettling would have withstood so high a degree of heat, and he believes that if there had been no lime in with the "tap cinder," it would have been one molten mass. Where the lining had been against the flue plate, the sand left on from the casting, at the middle of the plate, had not disappeared.

MR. R. HOWSON'S BLOW-PIPE PUDDLING FURNACE.

On the 28th of June, a charge was made, and timed, in Mr. R. Howson's experimental blow-pipe puddling furnace, at the Britannia Iron Company's Works, Middlesbrough :—

No. 4, Cleveland pig, charge, 1 cwt. 1 qr. 4 lbs.

	o'clock.	
Charged at	3·3	
	3·26	nearly melted, and partly boiling.*
	3·58	thickening.
	4·5	balled.
	1·2	

Two balls, weighing, unshingled, 1 cwt. 1 qr. 9 lbs.

The small experimental furnace being put up in too confined a position, the puddler suffered considerably from the radiating heat, and it was not found convenient to work more than one charge. The mode of regulating the in-flow of air and of gas has been left in a somewhat too experimental condition, which prevented Mr. Howson from working his furnace advantageously, as he otherwise might have done. No opportunity was afforded to examine the influence of the blow-pipe system on the quality of iron, and we beg to suggest to Mr. Howson the desirability of such an experiment. We enclose Mr. Howson's own description of the arrangement.

Mr. R. Howson's description of his Blow-pipe Puddling Furnace.

"It is worked by gas, and it is immaterial from what source the gas is obtained. It may either be produced in a generator attached to the furnace, or a number of furnaces may be worked from one generator, the latter arrangement being the one preferred. The kind of gas will vary according to its mode of production. For

* The furnace was not hot when the cinder and the pig was charged. The iron on which the greatest heat was thrown melted first, and the cinder underneath, on being rabbled up with that iron, produced a partial boiling before the whole of the charge was in a liquid condition.

metallurgic operations on a small scale, the ordinary coal gas of our towns may be most conveniently applied. For works on a larger scale, such as puddling, the system of generating impure carbonic oxide by the imperfect combustion of fuel (as adopted by Mr. Siemens), has been proved to answer the purpose; but as there is little doubt that carburetted hydrogen would be still more efficient, there is no reason why it should not be produced, in closed retorts, with economical results, either from coal or liquid hydrocarbons.

The furnace, in the form in which it at present stands, consists of a combustion chamber, the bottom of which forms the hearth, immediately above which is the opening in the roof, through which the gas and air enter, and there are two flues, branching in opposite directions, for the exit of the products of combustion. The entrance for the gas consists of a circular casing, presenting an opening downwards into the combustion chamber, and in the interior of the casing are a number of air nozzles, concentrically disposed. The entering gas is thus forced downwards in a corresponding number of flame jets immediately upon the centre of the hearth, over which it plays, and then escapes by the flues to the chimney. In order to economize the waste heat thus escaping, it is utilized in heating the gas and air, by causing them to pass through pipes which are situated in the flues or chimney uptake. The character of the flame, producible by this arrangement, is adapted in a special degree to the requirements of puddling. In the early stage of the process, an excess of air may be employed to advantage, to obtain the refining action of the free oxygen, and thus effect a saving in fettling; while, in the later stages, the granulated iron can be perfectly protected from oxidation by simply allowing the gas to enter slightly in excess. It might be supposed, at first sight, that, as the flame under this action is necessarily a short one, there would be some risk of wasting the iron, on account of its surface being so near (not more than 2 feet from) the nozzles, through which the air is forced. So far, however, is this from being the case, that it is perfectly easy to regulate the flame so as to be absolutely without free oxygen at the point where it touches the surface of the iron. The manipulation, for regulating the kind of flame required, is extremely easy, being effected, simply, by means of two handles connected with the air and gas valves. The flame is, in all cases,

entirely smokeless, for, although it is possible to produce a smoky flame, by causing an imperfect combustion, and thus wasting the gas, it is unnecessary to do so at any stage of the process. We have, here, then, a furnace free from the much complained of nuisance of smoke, and with special advantages which adapt it to the operation of puddling, while, in respect of economy, the saving, in iron alone, is a point of great importance, the waste from oxidation being reduced to a minimum. As regards the saving in coal, in the absence of direct experiments, there is every reason to suppose that, on a large scale, this would be considerable, since the consumption of gas is always proportionate to the temperature required, and during the intervals of rest, the consumption can be made to cease altogether, and at once, which is by no means the case with the ordinary fire-grate. It is to be regretted that the experiments, so far as they have been carried out with this construction of furnace, have been conducted on a small scale; their success, however, is such as to leave no doubt that the principle is applicable to a manufacture of any dimensions. The only drawback of any weight which presented itself, in the course of experiment, is, that the furnace works somewhat hot to the workman. This is in consequence of the chamber being always full of flame under a higher pressure than the air outside, so that there is a tendency of the flame to find its way out through any crevice or opening which may exist."

MR. JOHN GRIFFITH'S PUDDLING MACHINE.

The apparatus can be placed on any ordinary furnace. The machine (see Diagram) has a circular bed-plate, A, provided with ears, through which it is fastened to the bearers, B, over the furnace. Another circular plate or table, C, turning on balls which run in a groove in the bed-plate, carries the jib, D, to which the puddling rabble is suspended by the hanger, E. The same turning table also carries the standard, F, which supports the main gearing of the machine. The vertical shaft, G, passing through the

centre of the table, answers the purposes both of a main driving shaft and of a pillar, round which the machinery swings in giving the radial motion to the rabble; it is driven by bevelled gear communicating with the motive power by a horizontal shaft, H, passing beneath the bed-plate. A crank attached to the upper end of the vertical shaft gives motion to the hanger by means of a connecting-rod, I, and universal joints; and as the connection of the hanger with the jib is of the same free character, the motion communicated by the crank to the hanger, and through it to the puddling rabble, though mainly reciprocating, or from the front to the back of the furnace, is quite complex in its character, and resembles, as nearly as possible, the movement produced by hand.

A semi-rotatory motion is given to the circular table, C, before mentioned, by means of a shaft, J, at the end of which is a pinion working in a hollow endless rack, K. This shaft, which is driven by bevelled gearing from the main vertical shaft, has its chief bearing in the standard before mentioned (which is bolted to the table), and it is provided with an universal joint to enable its pinion to traverse the curves at either end of the rack. This rack is curved horizontally to an arc, described with the distance from the centre of the table as a radius, and it has a guide plate between the upper and lower rows of teeth, whereby the pinion is kept constantly in gear.

A flat bar, L, is firmly fastened at one end of the table, and at the other it is forked to receive the shaft on which the pinion works; so that, while the shaft is free to move vertically in traversing the ends of the rack, its lateral motion, produced by the pinion following the rack, is communicated by the bar to the table.

Thus the top of the jib, and consequently the forked hanger suspended from it and carrying the rabble, make a sweep from side to side in front of the furnace.

Only one rack is required for two machines working on the same furnace; the semi-rotatory motion being communicated to the table of the other machine by means of a flat bar, M, connected with both tables. The machine is thrown in and out of gear by a clutch, N, in the usual way.

Mr. Griffiths has also embraced with his patent the blowing of air through the puddler's rabble.

The movable fire-bars and smoke consumer, a sketch of which is shown in fig. 4, are also part of this invention.

The action of the bearers upon the fire-bars may be better understood by examining fig. 4, where the bars are shown in one of their extreme positions, the recessed ends being raised, and their opposite ends being depressed ; the bars in taking these positions moving at the same time horizontally in opposite directions.

When the bearers are in their middle position the surfaces of the bars are in the same plane.

By the motion of these fire-bars, the slag or other impurities may be detached from them and deposited with the ashes, without disturbing the burning fuel sufficiently to cause it to fall into the ashpit and be wasted.

Furnace.—The rabbling apparatus is applied at the Normanton Works to one double puddling furnace of usual construction, and of the following dimensions:—Length, 12 feet 7 inches; width, 7 feet 6 inches (inside the framework or plates); end walls, 9 inches; side walls, 15 inches; fire-bridge, 14 inches; length between fire-bridge and flue-bridge, 7 feet 6 inches; fire-grate, of ordinary construction, 4 feet by 5 feet.

The flame passes in a straight line through two boiler flues (the furnace flue being divided by a 4½-inch partition) into two stacks 42 feet high.

Engine.—The rabbling apparatus is worked by a 7½-inch diameter steam cylinder, 11 inches stroke, and from a 3¾-inch strap. 120 revolutions of the engine produce 60 single rabble strokes.

Apparatus.—The rabble hook is about 7 inches high and 4 inches wide, when new. During one heat, the rabble is changed from eight to ten times each side of the furnace. From the motion of the rabble, and from the form of the furnace, it is evident that in certain parts of the latter the iron cannot altogether be prevented from adhering or setting to the sides, and the puddler has from time to time to clear the breasts and jambs of the furnace by hand, which he does with each fresh rabble, before he hooks the same to the hanging bar. The motion of the mechanical rabble is guided by the puddler, and he can, to some extent, contribute to the advantage obtained in the use of the apparatus by a judicious management of the springs between which the hanging bar moves,

and by attention to the condition of the bottom of the furnace, and to that of the rabble itself, which, of course, keeps wearing. In guiding the rabble, the puddler has not to exert himself very considerably, nor is he so much exposed to heat as when working by hand, and, consequently, when the iron begins to thicken, and he commences gathering and balling-up, he is not in that exhausted condition in which he necessarily finds himself at that stage of the operation when puddling grey iron by hand. Every stroke of the mechanical rabble is naturally of the full length to which the apparatus has been set, and the speed of the tool is regulated at will. It is evident, therefore, that the advantage obtained by the apparatus is in more than a direct proportion to the weight and liquidity of the charge. Nevertheless, the presence of the puddler and his attention to the work is required all the time, and he has no rest from the moment when breaking-up begins, until the last ball is out.

Results.—In timing some heats made in an ordinary single furnace, working on iron of the same description as that charged in the double furnace, we found that 1,020 lbs. (510 lbs. per charge) of pig iron were puddled in two single-hand furnaces in 1 hour 40 minutes, whilst the double furnace, with mechanical rabbling apparatus, completed its charge of 1,200 lbs. of pig iron. The double furnace, therefore, converted during the same time 180 lbs. of pig more than the two single furnaces; or, putting both descriptions of furnaces on the same yield, 900 lbs. of pig *more* were worked by the double furnace in 5 heats, or 12 hours, than by two ordinary single furnaces. Whilst in the double furnace, the mechanical rabbles were in action, during an average time of 30·8 minutes, the puddlers at the ordinary single furnaces used their hand-rabbles for 36 minutes. No opportunity was afforded for comparing the consumption of fuel.

The double furnace was nearly new and in good condition. A large quantity of fluxes suitable for puddling steel was used.

In calculating the average results from the following table, charge No. 3 was not taken into consideration except for rabbling and drawing time.

	No. of heats.	Charge in lbs. of pig iron.	Time from charging to putting in of first mechanical rabble.	Time of mechanical rabbling.	Time from end of rabbling to first ball.	Time of drawing.	Total time.	Loss per charge of lbs. 1,200.	Loss per cent.	Produced per charge.	Production in 12 hours.	
		lbs.	minutes.	minutes.	minutes.	minutes.	hrs. min.	lbs.		lbs.	lbs.	
Not weighed in	1	...	...	25	20	13	...	...	...	...	...	
	2	1,200	54	30	16	10	1 50	124	10·33	1,076	5,380	
	3	1,200	43	42	15	23	2 3	270	22·5	930	...	
	4	1,200	46	32	15	7	1 40	150	12·5	1,050	5,250	
	5	1,200	53	25	17	13	1 48	138	11·5	1,062	5,310	
Average on			4	5	5	5	3	3	3	3	3	charges.
Average			49	30·8	16·6	13·2	1 46	137·3	11·143	1,062·6	5,313·3	

The rabbling apparatus described as a modification of Griffiths' patent puddling machine is applied to two furnaces at the works of Messrs. Palmer's Shipbuilding and Iron Company, Limited, Jarrow-on-Tyne, and one furnace is worked by the improved steam puddling machine, as described by Mr. F. W. Stoker, engineer at that time at the above works.

Furnace.—The following are the dimensions of the furnaces to which the rabbling apparatus is applied:—Length, 13 feet; width, 6 feet 9 inches (inside the framework or plates); end walls, 9 inches; side walls, 15 inches; fire-bridge, 14 inches. Length from fire-bridge plate to flue-bridge, 6 feet 6 inches. Fire-grate of ordinary construction, 4 feet 8 inches long and 4 feet 5 inches wide; one 2½-inch pipe with ⅜ holes, 4 inches apart, placed about 9 inches within the front wall, supplies blast to the grate.

Apparatus.—The remarks made in the report on Mr. Griffiths' furnace at Normanton, with respect to the working of the apparatus and the advantages obtained by the same, apply to all the different descriptions of mechanical rabbling, but the improvements in the newer apparatus must evidently decrease the wear and tear of the different parts of the same very considerably, and thereby render their application more efficient and more reliable.

MR. GRIFFITHS' APPARATUS.

Charge	1,970lbs. half white half grey pig.	1988lbs.
	o'clock.	o'clock.
Charged	10·35	1·20
Breaking up	11·25	2·0
Mechanical rabble in	11·38	2·20
Damper down (lead charged)	11·46	2·25
Damper up	12·0	2·40
Mechanical rabble out	12·0	2·40
Ready to ball	12·30	3·10
1st ball	12·36	3·20
Last ball	1·0	3·50
7 balls each side	Time, 2 hours 25 min.	2 hours 30 min.

APPARATUS AT JARROW.

Charge* (uncertain)	1,904lbs. half white half grey pig.	1,976lbs.
	o'clock.	o'clock.
Charged	11·35	2·10
Breaking up	12·12	3·0
Mechanical rabble in	12·30	3·0 still pasty.
Damper down (lead in)	12·36	3·10
Damper up	12·50	3·28
Mechanical rabble out	12·56	3·28
Ready to ball	1·20	4·0
1st ball	1·25	4·20
Last ball	2·7	4·38
7 balls each side	Time, 2 hours 32 min.	2 hours 28 min.

* Men charged sheets into 4 to suit their own convenience.

No. of heat.	Charge in lbs.	Time from charging to putting in of 1st rabble. Min.	Time of Mechanical Rabbling. Min.	Time from last Rabble to 1st ball. Min.	Drawing of 14 balls. Min.	Total Time. Hrs., min.	Loss per Charge. lbs.	Loss per cwt. on charge.	Produced per Charge for lumps	Production in 12 hours, or 5 heats.	
1	1,970	63	22	36	24	2 25	200	10·15	1,770	3 19 0 2	Machine—Griffiths.
2	1,988	60	20	40	30	2 30	313	15·73	1,675	3 14 3 3	
3	Uncertain.	55	26	29	42	2 32	Uncertain.	...	...	...	Machine—Jarrow.
4	1,976	50	28	52	18	2 28	271	13·71	1,705	3 17 3 17	
Average	...	57	24	...	...	2 $28\frac{7}{10}$	26,122	13·197	1716·66	3 16 0 26	

Results.—Four charges were timed, the results of which are given in the preceding page.

Mr. Ridley's opinion is, notwithstanding the successful mechanical working of the improved apparatus, that the saving in labour and fuel does not counterbalance the first cost and expense of any rabbling apparatus, combined with the difficulties connected with the men, and he is now putting up enlarged single furnaces to work 6 cwts. for hand puddling.

A charge of 4 cwt. 3 qrs.=532 lbs., was worked off in an ordinary single hand-puddling furnace in 1 hour 55 minutes, equal to 685 lbs. in 2 hours 28 minutes=1,370 lbs. in two single furnaces, against 1,716·66 lbs. in the double mechanical furnace, and puddled in the same time, viz., 2 hours 28 minutes.

The rabble bars being straight in Mr. Griffiths' machine, as well as in that of Mr. Ridley's at Jarrow, a certain amount of cinder and iron is thrown out with each stroke, if rabbling is continued after the iron has commenced to become grainy or sandy, and rises to the level of the fore-plate. The time of mechanical rabbling might be somewhat prolonged, but for that circumstance. That objection is removed at Messrs. Whitham's.—*See Report.*

DESCRIPTION OF THE NEW STEAM PUDDLING MACHINE,

Designed by Mr. F. W. Stoker, Engineer, and now in use at the Rolling Mills Department of Palmer's Shipbuilding and Iron Company, Limited, Jarrow-on-Tyne.

The general arrangement of the machine will be readily understood on reference to the drawings appended, and its manner of working is as follows:—The upper, or crank shaft, is driven by a chain, direct from the engine shafting, and in its rotation communicates a vibrating motion (through the ring round the crank pin, and the connecting rods attached thereto) to the suspension rods, which drive the rabbles in and out of the furnace. The crosshead or gudgeon, supported in the ring, has a bearing in its centre for the crank joint, and an universal joint is thus formed round the latter, the ring being of sufficient size to clear the crank at any part of its rotation. The vibrating motion of the wrought iron frame is obtained by means of a cam verged on the lower

shaft, and driven by toothed gearing from the crank shaft. The wrought iron frame is bolted to brackets cast on the circular table or disc, which has a spindle, cast on its under side; on to this spindle is verged a lever, in which is bolted a stud or pin, working into the recess of the cam, and the vibratory motion is communicated by the lever from the cam to the frame, and thence to the rabbles, or puddling tools. The recess in the cam is so arranged as to arrest the motion of the frame for a short period at each end of its stroke, but it is also curved so as to gradually increase the speed of vibration as the frame approaches the middle of its stroke (*i.e.*, the position in which it is shown in the diagrams), decreasing as it leaves the centre on either side, the object being to puddle thoroughly the iron in the sides or jambs of the furnace. The vibration may be increased or diminished by setting the stud working in the cam nearer to, or further from, the centre of the machine. The stroke of the rabbles can be altered by shifting the brackets which carry the suspension rods, but this has not been found necessary in practice. This machine started work in December, 1870, and has been running constantly since that time, having received no repairs or refitting of any description, and during the trial of July 4, 1871, showed no perceptible signs of wear. The advantages claimed for this machine are:—The peculiar periodic motion imparted by the cam; its fewness of moving parts; freedom from wear; accessibility for repairs if required; and great strength, combined with cheapness of production.

MR. A. SPENCER'S REVOLVING PUDDLING FURNACE.

The diagrams appended show the dimensions, the form, and general arrangement of the apparatus, which is at work at the West Hartlepool Iron Works (Messrs. T. Richardson and Sons).

The shape of the vessel is that of a rhombus, reversing on a horizontal axis. Its dimensions, as seen towards the end of June, were the following:—Grate surface, 3 feet 5 inches in width; 3 feet

9 inches in length; height from grate bars to centre of arch, 4 feet 5 inches; length of bridge, including brick-lining of rotary furnace, 2 feet 5 inches; working surface of rotary furnace, inside the fettling, 2 sides of 45 inches by 50 inches, 2 sides of 42 inches by 50 inches, taking the furnace in its then condition, with only one side of fettled trays or bars, the other three sides consisting of V-grooved plates, with about 2 inches of fettling; bridge flue, 2 feet 3 inches diameter; off flue, 1 foot 6 inches diameter.

Mr. Spencer, in his letter of the 9th August, describes the lining and working of his apparatus as follows:—

"The lining, which is simply what is technically known as 'mill or ball furnace tap,' an oxide of iron formed on the bottoms of furnaces by the heating of wrought iron piles, such bottoms being made of iron and free from sand, clay, or brick. This oxide is melted, and, when in the molten state, run on to the sides and ends of the revolving chamber, such sides and ends having dovetailed cells cast on to them. Thus, by the mechanical grip of the cells and the natural cohesion of the oxide, a very efficient lining is secured. One side of the chamber is formed in trays which run through full length, each tray being in section double dovetailed with cross bars (see tracing). In filling these trays with the oxide, a cast iron mould is used for forming the part facing the inside of the chamber (see tracing). This enables us to get a depth of two or three inches of very solid lining free from holes or honeycomb. I may add here that, having secured the ends and sides in the way described, the furnace puddled twenty heats without re-lining.

"The necks in the first experiments were lined with the best fire-brick; but this was soon abandoned, and recourse had to the oxide, which was applied to the flue-neck cold, but previously formed to the required shape in cast iron moulds. The bridge-neck was lined by running in the oxide in a molten condition, dam plates being placed in the chamber to keep the oxide from flowing down to the sides.

"There is little more to be said on the furnace in its present stage. The results have been very satisfactory, especially as to quality. The quantity produced per heat has varied from about 300 lbs. to 587 lbs. In a short time we hope to prove more fully the capabilities of the furnace, having a cupola and blower just ready, which will enable us to draw from 8 to 10 heats per shift."

After Mr. Spencer had made a small number of experimental heats in his rotary furnace, we were requested to see the apparatus and to examine its working on the 29th June, 1871, at the rolling mills of Messrs. Richardson and Son, West Hartlepool.

In the state in which we found the apparatus on the 29th of June, the following were its chief dimensions:—Grate of ordinary construction, 3 feet 5 inches wide; 3 feet 9 inches long—12·81; height from grate bars to centre of arch, 4 feet 5 inches; length of bridge, including brick lining of rotary furnace, 2 feet 5 inches; working surface of furnace inside the fettling, 2 sides of 45 inches by 50 inches in length, 2 sides of 42 inches by 50 inches in length; difference of level inside between shallow bottom and deep bottom, 8 inches; total heating surface inside the fettling = 60·41; bridge flue, 2 feet 3 inches diameter; off flue, 1 foot 6 inches diameter.

Three sides of the furnace were provided with shallow V grooves, holding the fettling, about 2 inches thick, previously cast on. The fourth side was constructed of "fettled bars," each bar being composed of two cast iron plates, an obtuse angle inside, and held together by bolts. The space between the bars was cast out with fettling, about 4 inches thick, previously. No cinder was charged.

29th June, 1871.—A charge was melted in a puddling furnace, and was carried in two ladles to the apparatus.

At 11·35 the first ladle was poured in through the tap-hole.

„ 11·39 the second part of the charge was poured in.

„ 11·42 tap-hole stopped up with clay and wedges, and the vessel set in motion at 4 revolutions per minute. A thin stream of water allowed to run on to the middle of the outside, and about a quarter of an inch stream on the neck of the apparatus, fire-bridge side.

„ 12·20 began to boil.

„ 12·33 the charge travelled from the lowest part of the vessel to from $\frac{1}{3}$ to $\frac{1}{2}$ of the length of the bottom and back, with each revolution, rather more than half of the quantity keeping itself on the fire-bridge side. The charge then lying on the parallel sides of the vessel slipped over the surface in the form in which it was received, without gathering. Some of the cinder oozed out through the joints of the neck, and some ran over into flue and fire-grate.

At 12·44 two balls formed themselves, the one towards fire bridge being larger. The outside of the plates were now inconveniently hot, so that any dust falling upon them ignited at once, although water was dropping on the outside plates during nearly the whole of the time, and a small jet was used to cool the neck where it turns in a short cylinder of the bridge-plate.

„ 12·52 stopped, and the door opened by sledging.

1 hour 17 minutes total time.

One ball, about 200 lbs. weight, was found somewhat raw, and would not shingle well. The second proved rather better.

At 3·30 p.m. a second charge was poured in. 1st ladle.

„ 3·34 „ second ladle.

„ 3·36 „ revolving at about 5 revolutions per minute.

„ 3·55 „ Some cinder and iron escaped through the joints and cracks of plates into the cylindrical joint, between the stationary and the revolving part, on the fire bridge side, clogging up the same, until at

„ 4·30 „ the apparatus completely stopped turning.

3rd of August.—17 heats made since the 29th of June, and 3 heats to-day. Several alterations had been made in the meantime. The cylindrical ends were cut off, so that the revolving part could work flat against the stationary part, a movable ring being stripped over the joint. A few holes were drilled near the angle of the vessel, in the fire-bridge end of the furnace, for the purpose of running in molten oxide to re-line the vertical end of furnace then required. During such re-lining the inside is dammed up by a plate. The said holes can be opened in case the cinder should run over.

At 11·35 the first charge had been run in.

„ 11·38 commenced to rotate at about 5 revolutions per minute.

„ 11·47 on the boil.

some cinder running over into fire bridge.

„ 12·0 iron rolling about in small lumps.

„ 12·10 balling.

„ 12·20 out.

Total time, 45 minutes.

Great difficulty in opening the tap-hole.

2nd charge in at 12·51
„ 12·55 rotating 3 revolutions per minute.
„ 1·6 boiling.
„ 1·17 dropping.
„ 1·33 balling.
„ 1·35 ready.
„ 1·40 out. 4 balls rolled into $3\frac{1}{2}$ inch bars.

Total time, 49 minutes.

The heat having been insufficient, the iron had to be reheated before it could be shingled.

The 3rd charge was run in at 2·25
„ 2·27 rotating, 3 to 5 revolutions per minute.
„ 2·53 boiling.
„ 3·8 some iron setting to bottom.
„ 3·23 ready.
„ 3·30 4 balls out.

Total time, 1 hour 5 minutes.

The heat was insufficient during that charge. The iron did not adhere or ball properly. A certain quantity remained sticking to the sides of the furnace, and the yield could not be ascertained.

On the 15th August, the experiment was renewed, with the following results:—

At 11·55 charged (not weighed) in a molten condition.
„ 11·58 revolving.
„ stoppage of several minutes.
„ 12·18 again revolving and boiling.
„ 12·35 balling.
„ 12·44 ready.
„ 12·50 out. One ball. Yield not weighed.

A second charge was made from the cupola. In wedging up the door of the revolving furnace, it broke through, and a new door was put in. But the fettling round the door-flanges had, it appears, been displaced, for when the door side of the furnace, in revolving, came underneath the molten iron, the latter ran out. The vessel was repaired and made ready for the next day.

On the 16th August, 6 heats were made.

1st charge in at 8·42 in a molten condition.
„ 8·50 set in motion, 8 minutes having been occupied in fastening the door.
„ 9·2 boiling.
„ 9·20 ready.
„ 9·27 out in 3 balls.
„ 9·35 rolled into 3-inch bars. Yield not weighed.

	cwts.	qrs.	lbs.	
2nd charge in	5	3	14	
	1	2	8	was found to have run out through the plates.
	4	1	6	remaining charge.

At 10·27 run in to furnace.
„ 10·35 stopped to allow the cinder to set, to cement the lining.
„ 10·45 boiling.

Cinder was found to escape through the joints of the machine at the fire-bridge end. The plates or casing of the furnace were red hot on each side, with the exception of the cross-bars over the cell side.

At 10·55 commenced to drop.
„ 11·0 rolling over in lumps.
„ 11·15 first ball out.
„ 11·20 4th ball out.

Total time, 53 minutes.

Yield 444 lbs. Loss, 38 lbs.

3rd charge.—Weight, 5 cwt. 0 qr. 10 lbs., in a molten condition.

At 12·15 charged and set revolving.
„ 12·35 boiling.
„ 12·45 dropping.
„ 12·55 balling.
„ 1·10 out in the ball.

Total time, 55 minutes.

Yield rails, 493 lbs. Loss, 77 lbs.

One ball was reheated and hammered twice into a bloom, which was taken over to the rail mill and bloomed, and rolled into a flange rail of 22 feet length, including the crop ends. The ball having been reheated in an uncompressed condition, and thereby somewhat burnt outside, the flange broke in two places. With that exception, the rail was sound all through.

	cwt.	qr.	lbs.	
4th charge.—	5	3	0	
	1	3	0	lost through the cell part of the furnace.
	4	0	0	remaining charge.

At 2·15 charged.
„ 3·10 ready.
„ 3·15 out. 1 ball.
Total time, 60 minutes.

This was hammered into a slab, and rolled out into a plate of $\frac{5}{16}$ of an inch in thickness.

The hammered lump, before being rolled into plate, weighed	385 lbs.
Loss	63 „
Charge	448

5th charge.—In order to try the cell-side of the furnace, the molten charge was poured in upon the same. The joints between the bars (the separate cells) proved, however, defective, and out of

	8 cwt.,	1 qr.,	16 lbs.	of iron,
	3 „	2 „	27 „	ran out.
The remaining charge was therefore	4 „	2 „	17 „	

At 4·25 ready.
„ 4·30 commenced to revolve.
„ 4·40 boiling.
„ 5·0 balling.
„ 5·7 ready.
„ 5·10 out. Made 4 balls.

2 bars of 7 inches were made of the charge.

Total time, 45 minutes. Yield 428 lbs.
Loss - 93 „

6th charge.—This charge could not be worked off. The flue lining had come off, and fell into the iron, the fettling having been worked off almost completely. The last 3 heats had been made almost without any fettling, and the casing was red hot all over except at the angles.

Twelve heats were made in all, on that fettling. The grate was supplied with blast.

On January 12th, 1872, Mr. Spencer writes:—"By the aid of the accompanying drawing, you will readily see the improvements made since my description, dated 9th August, 1871, consisting mainly in dispensing with the necks, which were attached to the revolving chamher or box; making the end plates round, with flanges on the periphery, so as to allow the chamber to revolve upon rollers at a greater distance from the heat; to the end plates are attached spur wheels, working to a pinion driven by a small engine; the four sides are formed of trays, the same as those previously illustrated; the doors, on the inner side, are honeycombed, the same as the end plates or discs; the faces upon which the doors rest have been arranged without recesses, thus simplifying the closing and opening. The chamber may be moved from its normal position by means of gearing, which propels the roller carriage upon rails; this has been arranged for the purpose of obtaining access to the ends, if required."

MR. WILSON'S PATENT PUDDLING FURNACE.

A few years ago, most of the technical papers had descriptions of the Wilson grate, or furnace, but, as far as we were able to ascertain, there are few of the furnaces in operation now.

Mr. Thomas Whitwell, (Stockton) who carefully followed up and studied the question from the commencement, has still a few of the Wilson furnaces in operation. He succeeded, by some improvements of his own, practically to apply Wilson's mode of firing, and he most obligingly consented to write the following short history, and description of the apparatus:—

"The distinguishing features of this furnace may be stated to be—1st. Complete combustion of the fuel, leaving only clinker and white ash. 2nd. The absence of fire-bars. 3rd. A considerable reduction in the amount of smoke produced by the furnace.

In 1866, the writer first saw the furnace. It was working at Milton and Elsecar, where the proprietors, Messrs. W. H. and Geo. Dawes, had a considerable number. At that time, the coal was

fed into a hopper, and burned on an inclined bank. The coal, burning away to white ash, required little attention as it fell down the bank, constantly exposing fresh surfaces till it was entirely consumed.

The cause of the failure of the furnace at these works was the demand of the men, 5s. per ton of bars, the moiety of the alleged saving from the use of it. A long strike ensued, during which the furnaces were pulled down, and the old form of furnace rebuilt.

In 1868, several furnaces were erected in Bolton by Messrs. Hick, Hargreaves and Co., and here again, as the coal burnt freely and fell to a white ash, the furnace merely required the solid bank on which the fuel rested rocking, from time to time, whereby the fuel descended, and fresh flame resulted from the movement. These furnaces were cleaned once a shift only, the furnace working quite black in the ash-hole.

The principle was also applied to furnaces producing black ash, and appears to give great satisfaction. Furnaces on this system have been used for some years by Messrs. C. de Bergue and Co. for heating the iron in rivet-making, the coal being perfectly consumed, and very little smoke being produced, the latter result is attained by introducing heated air through a perforated brick arch over the fire, which is one distinguishing feature in Wilson's patent furnaces.

In 1869, the furnace was put up at the Thornaby Iron Works, from designs by Messrs. Hick, Hargreaves, and Co. Here, however, in the first place, it failed entirely owing to the fact that the coal from the South Durham coalfield burns not to an ash, but to a refractory coke ; and as this difficulty had not previously been encountered, it had to be combated and overcome. After repeated trials, the necessary heat and flame, in its two qualities of length and clearness, were attained, and the furnaces worked without coaching, and produced excellent iron, good yield, and an economy of 20 per cent. in the fuel over a period. The lowest consumption of coal was attained one week in June, 1869, when 13½ cwt. only of coal was burnt per ton of puddled bar.

The distinguishing features of the improved furnace may be described as follows :—

The working chamber was the same as usual, and consisted of a coking chamber, into which the coal, chiefly "small," at 4s. 6d. per

ton, was fed by the underhand, so as to cover the arch technically called the "gauge." The coal rested on a brickwork bank, set to an inclination of one foot three inches in four feet. The distance of the gauge from the bank was 1 foot 6 inches, the width of the furnace 3 feet 6 inches, and the length of the bank from the gauge to the bridge 5 feet. Between the gauge arch and the bridge the roof was made of 9-inch bricks, with perforations, which conducted heated air from the upper chamber down to the incandescent fuel at that point where it was giving off its hydrocarbons, where by these the smoke producing gases were so consumed that the production of combustion at the top of the slack was with fair treatment clear gas. The heated air was obtained by the introduction of a current of cold air introduced by means of a steam jet $\frac{1}{16}$-inch diameter, at the flue-bridge, the air being forced round the furnace through the fire-bridge and lower bridge box, and thence by side flues to the hot-air chamber, whence it descended in jets among the gases. The lower end of the bank was terminated by a tymp, through which water circulated, flowing into the puddler's bosh; between the tymp and the fire-bridge was a space of 1 foot 6 inches, and below the tymp, at a distance also of 1 foot 6 inches, was the ash-pit bottom of brickwork.

The ash-pit was closed by doors at the back; above the doors was placed a tuyere, through which a $\frac{3}{16}$-inch steam jet inducted a powerful blast of air. The air and steam traversing the red-hot coke, gave a flame of great heat and regularity of carbonic oxide and hydrogen, which, combining with the hydrocarbons and heated air from the bank, produced the necessary heat on the puddling furnace.

The introduction of the blast, at the Thornaby Iron Works, changed a furnace that was more or less uncertain into a practical success, and believing in the ascertained saving of fuel, William Whitwell & Co. replaced a large number of their ordinary furnaces by patent ones. The necessary stirring of the fire was performed by side-poking holes on the bank, closed by falling slides. The fire was cleaned, when good coals were used, only once a shift, the clinkers frequently coming out in pieces 2 ft. wide, and the coal was perfectly consumed; but as it is well known that the puddler, or underhand, consider that the more they stir the fire at one time, the longer the flame will last, the volumes of unconsumed carbon was so great that

no amount of air could effect their combustion without snuffing the iron away during balling up ; hence a mean admission sufficient to clear the flame was all that could be allowed.

As regards yield, the furnaces were good, inasmuch as the lower blast always produced a large volume of flame which at all times filled the furnace, while the admission of top air could be regulated so as to produce a comparatively neutral flame; the hydrogen evolved from the decomposition of steam by the red cokes ordinarily thrown into the ash-pit and wasted also protected the iron.

The drawbacks of the furnace were:—1st. The necessity of good lighting up with round coals, as, if once hot, the furnace went well for the week, but if the small coal were wet, and the fire were neglected by the underhand, or not properly got up, a shift might be lost occasionally. 2nd. The tendency of the men on changing shifts to leave the back steam full on, whereby a large quantity of good coal and coke was uselessly wasted during the time that ensued before the succeeding shift came on. 3rd. The quantity of fuel which was necessarily wasted at the week end on the bank. 4th. Increased wear and tear and cost of repairs counterbalanced by the economy in fuel.

The men, however, began to be troublesome; first the underhands objected to the poking, and, going out on strike, were only quieted by 3d. a shift paid by the Company. Some of the men had been in the Milton strike previously, and the result was an intimation by the puddlers in general that they had no objection to the furnace, if the Company would make it worth their while to give them 1s. per ton on the puddled bars.

In the end the men struck for the shilling per ton. The Board of Arbitration was called in: they decreed that 6d. per ton should be paid to the puddlers, which, with the underhands' money, made upwards of 8d. per ton, to be paid to the men for royalty. Had the firm got their just returns from the trouble they had taken, the furnaces were commercially a success, but the only result of the demands of the men was to compel the firm to take down the furnaces, a fact that produced great lamentation among the puddlers, who found the extra allowance far more than repaid them for their alleged grievances before the Board. At the present date, a few furnaces still remain in full work, and, as proof of the success of the furnace, it may be stated that during 1870 much of the best

smithing iron made by the firm was puddled in Wilson's patent furnaces, some of the best puddlers in the works liking a Wilson's as well as common ones.

As regards fettling, the patent furnaces require slightly more than the ordinary ones, the blast giving a very hot flame. The experimental consumption of coal was found to be about 16 cwt. per ton of puddled iron, but the practical consumption was in reality little below that of ordinary furnaces, owing to the puddler's carelessness in not shutting off the steam when not required. This coal, however, being of a cheaper description, a saving on this head was effected, but this was lost in extra cost of repairs and allowance to puddlers and underhands.

In conclusion, the result arrived at seems to be that, so long as the puddler is paid by the amount of iron he gets out, the tool being the furnace, the masters will be obliged to make the furnace to the puddler's own satisfaction. The master may introduce what improvements he likes, but the only result will be that so long as there are more furnaces than men, the puddlers will simply leave the master and his improved furnaces and work at the place where he finds all things in the old style in which he has been educated, and where he is least interfered with.

The general result, therefore, is inimical to any improvement in the furnace, requiring greater attention on his part, and nothing but a substitution of another material such as steel and a new manipulation will prevent the wholesale waste of fuel seen in the common puddling furnace."

PUDDLING AND HEATING FURNACES ON THE SIEMENS PRINCIPLE.

GENERAL REMARKS.

The producers appear to be working satisfactorily at all the works. Blast is being introduced in some, but no definite results from that addition have been made known to us.

The cost of working the producers in wages only, is, on an average, about £27 to £28 per week for 20 producers, and it is considered that 1¼ producers are required for each double puddling furnace,

and 2 producers per heating furnace, each producer burning about 25 cwt. of coal per shift.

Nearly all the puddling furnaces are on the horse-shoe system, *i.e.*, the inflow and the outflow of the flame is on the same side of the furnace, separated by a partition wall.

The statements of the different works we visited agree in the following points:—

Puddling Furnaces:—Yield, on an average, ton per ton.

Quality, as with the common puddling furnace, depends on description of fettling used, and on the skill and exertions of the puddler. The difficulties which present themselves in working the puddling furnace are chiefly in the proper regulation of the heat, and it is no easy matter to get the puddlers so to attend to it, that there shall not only be the required *quality* of flame at the different stages of the process, but that the temperature shall not be lower on the outflow side than on the inflow side of the flame, and to get the men to reverse at the proper time.

Unless reversing is carefully attended to, the upworking flue becomes gradually over-heated, and the down flue, in a similar proportion, cooled too much; the consequence of which is, that, on again reversing, the furnace loses heat, and a rapid destruction of the flues takes place.

Repairs.—The weekly repairs are, on an average, very small and less important than those in the common puddling furnaces, the bridges and the partition wall requiring but a slight patching up. The crown holds out for 6 weeks, and a complete overhauling of the brickwork is found necessary about every 3 months, which takes from 8 to 14 days. Every 6 months the whole of the chequer work has to be rebuilt. Owing to the position of the side walls of the furnaces, in reference to the chequer work underneath, the latter cannot be removed, unless the furnace itself be taken down, which is a serious matter, as it cannot be rebuilt under a fortnight. The loss in bricks cannot be ascertained; sometimes the greater part of the chequer work bricks can be used again.

The bridges and the flues are built of Dinas Bricks, at £5 per 1,000. For the chequer work, the Glenboig bricks are used at 50s. to 55s. per 1,000.

The Dinas bricks assume a friable condition, easily falling to dust, not clinckering, and are, therefore, easily removed.

The Glenboig bricks stand the heat almost as well as the Dinas, but they melt and form a very hard lava-like substance, and, in dropping, choke up every crevice.

In the puddling furnace, a quantity of metallic particles float away with the flame; they strike against the back wall of the air flue, and combining with the silica bricks, they run down in the form of slag, and in this manner soon destroy the brick and the chequer work. When the partition wall between the air flue and the gas flue is partly burnt away from the top, and the floating particles reach the open space of the united flues, they lose heat to some extent, and adhering to the back wall of the air flue, there form an accumulation, which gradually lessens the surface of the flue sufficiently to interfere with the satisfactory working of the furnace.

Heating Furnaces.—The repairs in the heating furnaces are very trifling, and although the mill furnace requires more heat than the puddling furnace, the chequer work need not be touched for the space of six months, after which time it is found in a better condition than that of the puddling furnace proves to be after three months.

In the opinion of nearly all the firms, the Siemens furnaces are *perfect* in principle, and it is acknowledged that, when the sundry difficulties named shall be gradually overcome, the working of these furnaces may become far more general.

MESSRS. HANNAY & SONS, BLOCHAIRN WORKS, GLASGOW.

December, 1871.

30 double puddling furnaces on the Siemens principle. 12 heating or mill furnaces.

A double puddling furnace was made ready. A new scrap bottom was put on, and the furnace was fettled all round with a mixture of purple ore and hematite. A heat of 1,200lbs. of Dalmellington forge pig No. 4, rather hard, was charged at 12·35 p.m.—

1·25	P.M.	all melted.
1·35	„	boiling.
1·43	„	dropped.
1·55	„	ready to ball.
2·3	„	first ball out.
2·10	„	all out.

Whole in 1 hour 35 min.

Produced 1,122lbs., waste 78lbs. = $6\frac{1}{2}$ %.

Two balls put together; fours rolled into 18″ bars for plate. On the out-flow side of the furnace there was less heat than on the in-flow side. The men work five heats per shift. According to statement of the works, consumption of coal not determined. Fettling used and scrap for bottom more than in ordinary furnaces, but not determined. Quality of iron better than that from the common puddling furnace.

Repairs, same as stated in general remarks. Since the Siemens furnaces were put up, some puddling furnaces, on the old system, have been built. Heating furnaces; two, doing very well, making 22 tons of angle iron per shift. Two producers are reckoned to supply one heating furnace, making 11 tons per shift each producer, at 25 cwts. of coal.

Messrs. the Glasgow Iron Company, Motherwell Works.

6 puddling and 2 heating furnaces.

The statements of the firm are as follows:—

Siemens puddling furnaces—quality of iron produced equal to that from common furnaces—quantity rather more. Repairs considered to be very considerable, and scarcely balanced by advantages.

Mr. Thomas Jackson, Coats Iron Works, Coatbridge.

At the Coats Iron Works there are six double puddling furnaces, horse-shoe form, without mechanical appliances. They were built 8 feet 6 inches from breast to breast, but had to be reduced to 6 feet 6 inches, at which width they are found to work best. They make 5 heats per shift, equal to 50 cwts., charging 10 cwt. per heat.

The fettling used is a mixture of 2 parts purple ore, at 16s. per ton; 2, bulldog, at 12s.; and 1½ red ore, at 40s. per ton.

4 tons per shift, of 12 hours, are used of this mixture, together with all the scrap tap obtained from one scrap furnace, to produce 15 tons of iron. Without the scrap tap the quantity of the fettling mixture used is 5½ tons. We had no opportunity of weighing in and out, but, according to the statements of the firm, the yield is ton per ton.

There are 20 producers in use, and the weekly amount paid for labour is £27 10s.

Coal and repairs as stated in general remarks.

There are two heating furnaces which are doing very well, making 11 tons per shift, of 12 hours, and consuming about 4½ cwt. of coal per ton of iron. [See report of Blochairn.]

Monk Bridge Iron Works, Leeds, Siemens Furnaces.

August, 1871.

Two single puddling furnaces, with mechanical rabbling.

Charge, 566 lbs.; cinder, 500 lbs.; for girder iron.

The rack for regulating the gas supply has 25 working teeth, or, with 25 teeth the maximum of gas is given.

12·19	Charged with 3 teeth of gas.
12·33	5 teeth of gas.
12·40	Breaking up.
12·50	Melted. 7 teeth.
12·55	9 teeth.
12·57	6 „
12·58	5 „
1· 1	6 „
1· 2	10 „ Air nearly shut off.
1·12	Damper down.
1·13	4 teeth.
1·19	3 „
1·22	2 „
1·29	Dropped.
	Turning over, spreading, gathering.
1·37	First ball.
1·57	All out. 4 balls.

Whole time, 1 hour 38 minutes.

Iron made lbs.	546
Loss	20 = $3\frac{5}{8}$%
	566

Single furnace, flame running from end to end. The men are said to like the Siemens furnaces so much, that they will not work the common puddling after they have become well acquainted with the gas furnaces.

Messrs. Clay, Inman, and Co., Birkenhead.

One single puddling furnace; out at the time. The firm are very well satisfied with the results, the yield and the quality being favourable. The fettling used consists of three barrows of red ore, and three of best scrap tap, every 24 hours, or 12 heats, making 6 heats per shift. Charge, 4 cwts. 1 qr. 6 lbs. Repairs, as stated in general remarks. A number of heating furnaces are in activity for forgings, one of very large dimensions, and these furnaces give complete satisfaction. The ease with which the largest forgings are heated equally on all sides, and without wasting the iron, is very remarkable, and beyond all comparison superior to the former arrangements. Messrs. Clay, Inman, & Co. are perfectly satisfied with the Siemens system, and more heating furnaces are being put up.

Garston Iron Works, near Liverpool.

Three double puddling furnaces, have only worked a short time. One was standing. It had been started on the 17th November, 1871, and was in activity for a fortnight, when the chequer work was found choked up.

The firm state that, so far, no satisfactory results have been obtained. More fettling is required, per ton of iron, than in the old process; yield, about the same, but quality inferior to that from the common puddling furnace.

One heating furnace in mills. It is considered inferior to the draught furnace, and when best iron is required, the latter furnaces are used.

Cost of alteration of four mill furnaces :—

100,000 bricks...	75,000	at 72s. 6d.	=	£271	17	6
	25,000	„ 21s.	=	26	5	0
16 tons clay ...	...	„ 9s.	=	7	4	0
Labour ...	...	... ...		120	0	0
				£425	6	6

10″ mill was stopped 8th June, 1871; re-started 9th Aug., 1871.

16″ „ partly heated from Gorman furnaces, from 14th April to 21st September.

The Bolton Steel Works.

One single Siemens puddling furnace, not always in use. It has worked most satisfactorily. For two months, 3 shifts were made per 24 hours, 6 heats per shift, 18 heats per 24 hours; quality and yield very satisfactory. Fettling used, very considerable; coal not determined. Repairs, see general remarks.

For heating small piles of iron, the Siemens furnace has not been found suitable at these works, but, on the other hand, it has never failed to give favourable results, when used for steel, or for large masses of iron.

The advantage of the gas furnaces in heating forgings has been very considerable, and according to the shape and size of the forgings, the saving over the old mode of heating has been from 15 to 30 per cent.

The wages for twelve producers are, on an average, from £11 to £11 2s. 6d. per week.

The Gorman Heating Furnace, Coatbridge Iron Works, Coatbridge.

The firm state that about two years ago, a heating furnace, on Gorman's heat-restoring principle, was put up, and the same furnace is still in use. The stoppages which now and then occur, arise from the breaking down of the steam fan, and the necessity of blast is regarded as almost the only objection to the plan, which otherwise has given complete satisfaction. The consumption of fuel is 6 cwt. per ton of iron.

The flame is easily regulated, and the piles come out of the furnace with edges almost as sharp as before charging.

The Howatson Puddling Furnace at Coats Iron Works, Coatbridge.

Two such furnaces were put up with all care, and in accordance with Mr. Howatson's description and instructions. The furnaces soon worked very hot, and an unusually large quantity of fettling was used. Gradually the fettling came off altogether, and, at the

end of the second week the bottom of one of the furnaces dropped right through. In order to prevent a similar occurrence with the second furnace, the side air flue was opened, and afterwards both furnaces were worked in the usual way, and still continue to be so.

Patent Puddling Furnace of Ben. Bayliss, Workington.

At the works of Messrs. Price, Dixon, and Co., Workington, Cumberland, the patent puddling furnace of Mr. B. Bayliss is said to have been erected and worked experimentally. The apparatus was, however, no longer in use, when we heard of it, and we, therefore, did not visit the works.

We have written to Messrs. Price, Dixon, and Co. for information on the subject, and append the general statements they have supplied to us:—Mr. B. Bayliss states, that to put up a furnace it would require, besides the driving power, castings from 7 to 8 tons; bricks, 16,000 to 18,000; mortar and clay, about 9 tons; labour, £12.

Mr. Bayliss proceeds to say that the mode of operating is as follows:—The first or melting chamber is charged. When the iron is melted and run into the second chamber (or fining compartment), another heat is charged into the melting chamber. The first charge, on being properly fined, is run into the third chamber, there to be puddled, and the two operations of melting and puddling are carried on simultaneously and continuously, with very little more coal than is consumed in common puddling furnaces. Very little fettling is said to be required, the iron being thoroughly refined on reaching the puddling chamber.

The bottom of the melting chamber is kept in repair by a little sand thrown in every three or four heats.

The fining compartment being constructed with water blocks, would not require lining more than once a week with bricks. Fire brick tuyeres answer very well. The puddling chamber is under perfect control, and after having been well fettled to begin with, it is kept in repair by a little scale from the rolls being thrown in, where a cavity may present itself; the doors work satisfactorily and give no trouble.

The arrangement of the teeth in the puddling tool is so, that not

an inch of the surface remains untouched. With properly fined iron, two puddling tools are sufficient to bring the iron to ball. By a simple contrivance, not shown in the specification, the tools are easily changed and put into position. When ready to ball, the iron is allowed to rest for a few minutes, in order to consolidate. The balling tool is then introduced through the top, and by its own weight, it will divide the charge as required.

B. Bayliss' Patent Puddling Furnace and Apparatus

January 25th, 1872.

A report on the experimental working of Mr. B. Bayliss' puddling furnace, and apparatus, has been received by us to-day, from Messrs. Joseph Price, jun. & Co., Marsh Side Iron Works, Workington.

Messrs. Price state that, at the commencement, they looked upon the experiment as an experiment only, and that, therefore, the arrangements were not made so systematically and so completely as might have been done, and they own that Mr. Bayliss had not the facilities he ought to have had, for trying his process thoroughly.

To start with, it was found difficult to heat two chambers with one fire, and when they had successfully disposed of that difficulty, they found that their blowing engines were too weak to supply sufficient blast for the fining chamber. Such a defect could only be remedied by the erection of a new engine, which would necessitate considerable expenditure, and, for that reason, the process was not carried out more fully.

The iron made was remarkably good; little or no fettling was used, and repairs would be similar to those required in an ordinary puddling furnace. If heated by gas, Messrs. Price are of opinion that the furnace would easily make from 10 to 12 heats of 10 cwts. each, per shift of 12 hours. The rotary (puddling) tool worked well. The balling tool was not tried.

Blochairn Iron Works.—Henderson's Process.

December, 1871.

On our arrival at the Blochairn Iron Works we found there Mr. Henderson, who was trying his process in the puddling furnace.

We were present at one heat, which, however, did not give a satisfactory result, some of the iron having gone through the bottom. Mr. Henderson fettles the bottom of the furnace with a mixture of oxide of iron and fluorspar. The iron is then charged on thin layers of wood, in order to prevent the mixture adhering to the pig, and the charge is then melted down as usual. The mixture is said to remain hard until all the iron is melted. Then, the mixture gradually melting, gives out its gases, which thoroughly permeate the iron, decarbonising and purifying it from silica, sulphur, and phosphorus. When that action has taken place, the iron drops, and all that the puddler has to do, is balling up. Mr. Henderson had a collection of very excellent samples, some of which had been made at the Blochairn Iron Works. The charge made in our presence worked as follows:—

12· 5 p.m., charged 1,200 lbs. in a double Siemens furnace.
12·40 „ all melted and left untouched till
2·11 „ it was then partly boiling, the intense heat, however, melted away the fettling, some iron and cinder ran through between the breastplate and the bottom plate, and the heat had to be rabbled and finished, in the usual way, to prevent its going through altogether.
2·30 p.m., dropped.
2·40 „ ready.
2·45 „ all out. Produced 883 lbs. Loss, 317 lbs.

HOWATSON'S PATENT PUDDLING AND HEATING FURNACE.

About 400 of these furnaces are either at work or in course of erection in various parts of England and Scotland. The invention consists in the application of hot instead of cold air to the grates of puddling and heating furnaces for the construction of the fuel. The principle is not new, as attempts were made more than twenty years back to utilize the waste heat of the furnace, by conveying the air through passages where this heat was absorbed before delivering it to the fire grate, and at the present time, there are

patent furnaces working in which hot air alone is supplied for the combustion of the fuel.

The figures in the accompanying diagrams will illustrate the construction of the furnaces; they are not working drawings, and are only intended to show the arrangements which have been slightly altered in the most approved furnaces. The application to a heating furnace is as follows:—All the ordinary air passages are stopped up (see Fig. 5); the opening under the grate at the end of the furnace by a sliding sheet-iron door, actuated by a balance weight and a cast-iron swing door, and the hole through which the fuel is charged by a hanging cast-iron door. These doors are immediately opened when necessary, as at the time when the fire bars are cleaned. By this means all air is prevented from entering the grate end of the furnace, and that necessary for the combustion of the fuel is drawn from the stack end. At the bottom of the stack or chimney there is a square opening, and above it several perforations in the brickwork (see Figs. 2 and 6), through these the air enters and passes into flues surrounding the base of the stack (Fig. 3,) where it becomes heated by contact with the sides of the said flues; it is then conducted round the neck of the furnace into a series of parallel horizontal passages under the bed, from whence it enters the opening under the fire-bars, and reaches the fire at a high temperature. The application of the patent to a puddling furnace is slightly different, as the cold air is first admitted under the bed, which it cools and preserves, and then passes round the base of the stack, along the back of the furnace, (see Figs. 7, 8, and 9), and is delivered in a highly-heated state under the grate. A simple apparatus is provided to thoroughly consume the gases generated by the fuel, and prevent smoke. By another arrangement, the pig iron is melted in a separate chamber of the puddling furnace by the waste heat, and when the charge is drawn is ready to run down into the puddling chamber and be worked.

These latter appliances have been tested by the inventor with good results, but are not recommended, as they require more than ordinary attention from the men.

The inventor says that, by the adoption of these arrangements, a saving is accomplished of from 20 to 25 per cent. of fuel, and a large percentage of iron, together with other advantages. In the

puddling furnaces the bottoms are preserved, fettling is saved, the yield is increased, and the brickwork lasts longer, in addition to the saving of fuel; in the mill furnaces more iron can be heated, the heat is more uniform, or "soaky," as the men term it, the piles or blooms are not cut away so much, the linings require renewing far less often, and the iron rolls better, there being fewer bad ends, so that it can be cut or sheared much longer than formerly. At the Earl of Dudley's works, where the furnaces have been longest in operation, the inventor states that those in the small mills save about 6 tons of coal, and over a ton of iron per week, besides the saving in cropping from having better ends.

THE HEMATITE IRON ORE DEPOSITS OF FURNESS.

By P. WÜRZBURGER, Dalton-in-Furness.

The rocks of the iron ore district of Low Furness are closely connected with those of the Lake district, and have been frequently described by Sedgwick, Harkness, Binney, Nicholson, and others. It is, therefore, only necessary here to mention these rocks in a few words.

A. THE ROCKS OF THE DISTRICT.

Within the area of the appended map* there are, in an ascending order, the Lower Silurian, Carboniferous, and Permian formations in a great part covered by Drift.

I. The *Lower Silurian* is represented by rocks of Caradoc age, namely :—

1. Green Slate.
2. Coniston Limestone.
3. Coniston Grits and Flags.

The latter, forming the upper division, are by far the most important, the two former rocks appearing on High Haume, to no great extent, merely in consequence of having been lifted up. This upper division is steeply inclined, and subject to numerous foldings. The light coloured grits are less frequent than the flags, which are of a bluish grey colour.

II. The *Carboniferous Rocks*, with their lowest division, the Mountain Limestone, rest unconformably upon the grits and flags.

The Mountain Limestone, covering the greatest area of the district, contains the hematite deposits, and has a general inclination

* Topographical part taken from Ordnance Map, on reduced scale. The Government Geological Survey of the district has not yet been published.

of from eight to twelve degrees. Only near Park Mines, in consequence of the local disturbance of High Haume, we find, together with an anticlinal bend of the strata, inclinations up to 45 degrees. The lowest beds consist of dark shales, conglomerates and beds of dark grey limestone, upon which light grey limestone beds follow. The latter predominate, they are frequently coloured red by peroxide of iron. It deserves to be stated, however, that, in the immediate proximity of the iron ore deposits, both red coloured and perfectly white limestone beds are found.

The general dip of the limestone, if we except the north-western part of the area, is towards south-east. Only between Stainton and Gleaston Castle appears a small synclinal bend, which seems, however, to be confined to that locality.

The limestone extends eastwards into the Cartmel district, and terminates in the north-west at Dunnerholme, followed by the Coniston Flags. It re-appears on the other side of Duddon, where the important hematite mines of Hodbarrow are situated, continuing most probably, and likely, ore-bearing also, under the estuary of the river.

The upper division of the carboniferous rocks is formed by the Black Shale, which rests conformably upon the limestone, and is identical with the Yoredale Shale. The beds are dark grey, and contain, besides their characteristic plants (chiefly *Sphenopteris*), numerous nodules of ironstone (carbonate of protoxide of iron) from a few inches to two feet in diameter, which, being strongly impregnated by pyrites of iron, are of no technical value for the produce of pig iron. This shale has been sunk through at Stank, where, the Mountain Limestone having been reached in about 62 fathoms depth, further sinking led to the discovery of a valuable hematite deposit.

The true coal measures, with seams, and the distinguishing plants of *Sigillaria, Stigmaria,* &c., are nowhere visible in Furness. Their occurrence under the Permian rocks in the southern and south-western parts of the district, in greater distance from the Mountain Limestone and black shale,* although not quite certain, is, at least, not impossible, and, in connection with faults, which undoubtedly exist, is favoured by the flatter dip of the Permian rocks.

* At Hawcoat and Rampside, trials are going on.

III. *The Permian Rocks* are, in extent and thickness, chiefly developed in their upper division. The lowest member of the group, "Crab Rock" (not marked on map), is a breccia of Mountain Limestone fragments, which occurs only in a few detached places of the district, for instance, near Park Mines and Dalton Church, unconformably reposing on the Mountain Limestone, in no particular thickness or extent. The only place of the district where the middle division, the Magnesian Limestone, comes to the surface, is at Old Holebeck, south of the village of Stank. The rock, of a yellowish colour, exists there in a thickness of about 15 feet only, resting on Black Shale.

The *upper Permian Sandstone,* with a general dip, an angle of about 5 degrees to the south or south-west, is of a light red colour, and occupies the south-western part of the district. Resting on its northern border, from Sandscale House to Sinkfall, on the Mountain Limestone, it is in its more southern turn, between Millwood and Parkhouse Mines, brought side by side with the limestone, in consequence of a fault which effected a considerable downthrow of the latter in its western course.* Still more south, we find the Red Sandstone joining the Black Shale.

The thickness and exact nature of the Permian Rocks may be said not to have been completely ascertained as yet. Their thickness is certainly very great. The quarry and borehole at Hawcoat have penetrated beds of Red Sandstone without change to a total depth of about 130 fathoms, while, at Rampside, the Permian rocks were bored to about 116 fathoms depth. At the latter place, the beds consisted (after 13 fathoms of drift, and two fathoms of Red Sandstone) of what is supposed to be Magnesian Limestone, under which beds of calcareous sandstone were gone through. A new borehole, at which, as at Hawcoat,† boring cores are brought to the surface, will throw better light on the nature of these rocks.

IV. The before-mentioned formations are overlaid in many places by Drift, consisting of boulder clay, sand, and gravel, and varying in thickness up to 30 fathoms and more; the average thickness is from five to ten fathoms.

V. Of crystalline rocks, confined to a few isolated places, are to

* Besides other trials, a borehole, close to the west of Parkhouse Mines, went about 63 fathoms (total depth) through Red Sandstone without coming to limestone.

† Although on a different principle.

be named a red felspar-porphyry, associated with the Permian Sandstone, at Gleaston, and greenstone-porphyries and amygdaloid, which occur in connection with the Lower Silurian rocks of High Haume, and Hare Slack Hill.

B. THE HEMATITE DEPOSITS.

The deposits of red hematite are contained in the Mountain Limestone, both where the latter rock, covered only at places by drift, exclusively occupies the country, and where it is followed by black shale, as the Stank deposit recently has proved. The length of the area in which, with very unequal distribution, the deposits have been found, may be stated to be 7 miles (from Roanhead and Askam, in the west, to Plumpton, in the east); the breadth, which varies considerably, is greatest between Martin and Stank—about 4 miles. The greatest concentration of the ore appears between Duddon and the mines immediately east of Lindale, in a zone surrounding High Haume. There can be no doubt that the great disturbance of the latter hill affected also the Mountain Limestone by lifting it up, and thus producing a broken character of the rock, which highly favoured the deposition of the ore. A probably closer nature of the limestone further east of Lindale seems at least to be the reason that no greater deposits have been found there.

The deposits of Furness, which produce at present annually about 800,000 tons of ore, may be divided into two main classes:—

1. Deposits filling out irregular hollows.
2. Deposits of a vein-like appearance, filling out fissures of various width.

Both sorts are sometimes combined. The difference is one more of degree than of kind, the ore in the vein-like deposits being more intermixed with masses of limestone. The longitudinal extent of the deposits coincides in the most cases very nearly with the direction of the dip of the limestone, thus intersecting the beds almost at right angles, so that in a great part of the district a certain parallel run of the deposits is produced.

The following table shows the two classes of deposits as worked by the various mines of the district :—

Deposits in Hollows.	Deposits in Fissures.
Askam.	Bolton Heads.
Carr Kettle.	Gilbrow (Lindale Moor).
Cross Gates.	Lindale Cote.
Dalton Mine (Denny's).	Longlands.
Ditto. (Clegg's).	Lindale Moor
Eure Pits (Ulverston M. Co.)	Newton.
Elliscales.	Oldhills.
Green Haume	Pennington.
Lindale Moor (California).*	Plumpton.
Mousell.	Stainton.
Park.	Stank.
Parkhouse.	Tarn Close.
Poaka.	Thwaite Flat.
Roanhead.	Urswick.
Stonefolds.†	Whitriggs.

Both kinds, which appear in about an equal number, vary considerably in their dimensions. They are, as a rule, wider near the surface cover than lower down. It happens sometimes that a deposit widens out downwards in a conical shape, as, for instance, at Askam mines; but even at such places there is at last a turn in the dip, causing the width to lessen as the depth increases.

Deposits in hollows.—The largest deposit of this class is one which is worked at Park, and in its western part at Roanhead Mines. It fills an irregular hollow, and extends from east to west, with various curves, upwards of 500 yards in length, by a width of from 120 to 240 yards. Overlaid by about 10 fathoms of drift, ore has been proved to exist to a depth of 70 fathoms, the deposit extending still further down. The dip‡ of the walls, which surround this deposit changes frequently, and varies from 40 to 80 degrees. The walls on the north and north-western side dip in the main towards south; but at some places the dip is reversed. The south side shows inclinations towards both north and south; while the east wall has a dip towards west.

* East of main deposit.

† West of Lindale Tunnel; formerly belonging to Mr. Rawlinson, now to Furness Co.

‡ Independently of the dip of the strata, which is in the neighbourhood of the deposits frequently obscure.

The deposit of Askam mines, worked by two companies, extends from east to west, about 400 yards in length, by about 300 yards greatest width, the deepest levels being at present 45 fathoms below the surface. This deposit is remarkable for the flat dip of its western wall, at an angle of about 45 degrees towards north-west. The "rock roof" thus formed requires special precaution in the getting of the ore, compared with the working of most of the other deposits, where the loose surface cover gradually subsides, in proportion as each "height" of workings is taken out.

The majority of the other deposits belonging to this group are of less dimensions, some of about 100 to 120 yards length, by 40 to 80 yards width, others of still smaller extent. Some of the latter were found exhausted in 30 fathoms depth, and even less. In some places, they are of a pipe-like appearance, the depth being greater than the horizontal extent.

The hematite which fills the deposits described, resembles a huge chemical precipitate. It possesses various shades of red, and is frequently of a brownish and steel-grey tint, the brownish red colour being produced by admixture of clay and peroxide of manganese. For the most part the ore consists of minute particles, generally not very firmly connected and of a soft nature, in which larger and harder pieces are imbedded. The corners of these latter, the majority of which are less than one inch in size, are sometimes slightly rounded, probably by the action of percolating water. Some of the softer ore is used as "puddling ore." Besides this looser ore, generally got by the pick, there are masses of harder* hematite which require blasting, their hardness being produced by a slight admixture of silica. Kidney ore is found both in cavities and imbedded in more or less loose hematite; in the former case, it is frequently accompanied by ironglance and quartz.

The deposits contain, besides the ore, detached pieces of limestone, red and white clay filling out fissures; to these must be added a white or light red sand, sometimes assuming the character of a soft sandstone, which closely resembles the Upper Permian Sandstone. This sand is, however, only found at the mines situated near the junction with the Red Sandstone, as at Park and Parkhouse mines, and other places. Its close connection with the ore seems to prove that the deposits have been formed at the time of the Permian rocks.

* At Askam mines exclusively.

Of other minerals found at places in the deposits, are to be named, besides calcspar, pyrolusite (peroxide of manganese,) and barytes of a light red colour. Pyrolusite forms either a thin coating on kidney ore, or, mixed with sandy clay, is frequently found in a thin layer between limestone and ore.

Vein-like Deposits.—The general course of most of these deposits is from north-west to south-east. Their dimensions vary like those of the former deposits. From small fissures of a few feet width and depth, like some veins at Boltonheads, we find, at Lindale Moor and Whitriggs, veins up to 1,000 yards in length, and 30 yards greatest width. The deepest levels at Lindale Moor, without coming to a termination of the deposit, are 60 fathoms below the surface.* Although the working of some veins in the district has been stopped in depths from 30 to 40 fathoms, the ore most likely extends further down, as it is frequently cut off by masses of limestone.

The ore is found in strings, sometimes running more or less parallel, sometimes net-like connected, their width varying from a few inches up to 10 yards. The remaining space of the veins is occupied by limestone of a very jointy nature, frequently broken into large pieces, the joints being filled with iron ore. The rock thus causes interruptions both in a longitudinal and cross direction of the veins. The strings of ore do not always extend to the surface; sometimes they assume a more bed-like appearance, by being parallel to the strata of the limestone, a feature so common in the Whitehaven district.

The dip of the veins is generally very steep, at an angle of 70 to 80 degrees, in the most cases towards the west. At Whitriggs mines, the foot wall is found to be less broken and jointy than the hanging wall; but this seems hardly to be the rule, as in other deposits small veins proceed from both walls.

The ore in the veins resembles, on the whole, that of the former class. The "puddling ore" is, however, of a richer quality; it is greasy in appearance, and of a brighter red colour than that of the larger deposits.

Origin of the Ore.—The impression derived from the observation

* The deepest shafts in the district are those of Stank mine; the ore, chiefly of a hard nature, is at present worked there at 95 fathoms total depth, although only 33 fathoms from the top of the limestone. The ore probably extends up to the black shal

of the hematite in this district is, that it is of a chemical aqueous formation. The most important deposits are found at or near the junction with the Silurian Rocks, which, in some cases, even form the foot wall of the deposits; hence, we are led to infer that the ore may have been formed by water containing carbonic acid percolating the Silurian Rocks, and it thus became charged with bi-carbonate of protoxide of iron. Filling the hollows and fissures of the limestone, the bi-carbonate was changed into peroxide, for the greatest part by the action of atmospheric oxygen, but to some extent also by taking the place of limestone. This last is proved by Mountain Limestone fossils which have been found in the deposits, changed into hematite ore.

Although the Silurian Rocks limit the extent of some deposits, it is probable, from the cavernous nature of the limestone, that, further from the older rocks, hematite ore may be found at greater depths than have been hitherto known. As the veins are, in most cases, steeply inclined, and the walls of the larger deposits sometimes overhanging, it is further evident, that in order to find the ore, even in moderate depths, boreholes and trial pits should be put down sufficiently deep, and at no great distances from each other.

QUARTERLY REPORT

ON THE

PROGRESS OF THE IRON AND STEEL INDUSTRIES

IN FOREIGN COUNTRIES.

By DAVID FORBES, F.R.S., &c.,

Foreign Secretary to the Institute.

1872.—I.

A. METALLURGICAL TOPOGRAPHY.

Austria.—In consequence of the coal, obtained from the greater number of the collieries now worked in this country, being so poor in bituminous matter as to be unsuited for the production of good coke, a series of experiments, on the large scale, have recently been made at Sulzbach, near Saarbruecken, by Director Besecroth, at the instigation of the Austrian Government, in order to determine whether, by using the Appolt and Francois coking ovens, and mixing the Austrian coal with various proportions of more bituminous coal from the Saar district, or from the Moravian coalfield, a good hard coke adapted for iron smelting in blast furnaces could not be produced economically. The results of these trials show that this object could not be attained without employing, at the lowest, three parts of bituminous to two parts of the lean coal, or more satisfactorily in the proportions of seven of the former to three of the latter.

At the Creuzot Iron Works, in France, the coke made use of in the blast furnace is produced by mixing the lean Creuzot coal with the more bituminous coal from St. Etienne, and coking in the Appolt ovens.

The Franco-Austrian Company, during the year 1870, turned out 3,629 tons of steel against 2,389 tons in the preceding year; this increase of 1,240 tons would have been considerably greater, but for the serious accident which occurred in the preceding winter, in which several of the employés were victims, and which occasioned a stoppage of nearly three months. Included in the total of 3,629 tons of steel, in 1870, are 2,202 tons made by the Bessemer process, (being 840 tons more than in the year before), of which 1,620 tons were turned out in the shape of rails, and 164 tons as weldless tyres.

Belgium.—The iron trade in this country continues in a very prosperous condition, orders flowing in on all sides, and the production everywhere falling short of the demand; pig iron is, consequently, becoming scarce, and prices are well supported; fuel has advanced in price, and much difficulty is still experienced from the want of sufficient rolling stock, on the railways, to keep the blast furnaces supplied with coal and ore, so much so, that many of them have been kept on short allowance, and some have even been blown out from this cause.

The last statistical accounts received, bring us up to the commencement of the last quarter of 1871, and are as follows:—

Imports in Metrical Tons	For the month of September. 1871.	1870.	For the first nine months. 1871.	1870.
Iron ores	55,084	29,475	—	—
Pig and scrap iron	14,949	9,377	68,205	68,097
All iron goods, excepting minerals	15,645	9,890	73,591	75,437
Exports.				
Iron ores	12,333	9,338	128,150	136,734
Pig and scrap iron	6,180	306	29,686	5,361
Rails	4,943	12,643	64,574	106,532
All iron goods, excepting minerals	19,490	23,231	184,886	202,049

From these figures it will be seen that there is a falling off in the exports of no less than 17,263 tons, as compared with those of the corresponding period of the preceding year, and that the Belgian iron trade has not, as yet, recovered the position it stood in previous to the Franco-German war.

It is estimated that the production of pig iron in Luxemburg will, this year, reach 300,000 tons, a figure which, if realised, will be an increase of about 158,000 tons on the make of 1871, and will result from the working of six new blast furnaces, whose united daily yield is calculated at about 440 tons.

Efforts are being made, in various directions, to make Belgium more independent as regards to steel. The Ougrée blast furnaces,

which, by a late royal decree, have been authorised to put up considerable extensions, have commenced to manufacture steel, and the Seraing Iron Works are about to follow their example. A new establishment for making Bessemer steel has also been founded at Angleur, a suburb of Liége, on the right bank of the Meuse, which is under the direction of M. Gustave Pastor Junior, and is called the Angleur Steel Works Company.

Several new engineering establishments are projected, and the manufacture of drawn iron tubes is now said to have become successfully established at Liége.

A paper was recently read before the Association of Engineers, at Liége, by MM. Raskin and Grenier, on the revision of the treaty of commerce between Belgium and France, and its effects on the Belgian iron and steel trades, but does not contain anything likely to prove of much interest to our readers.

We have received from Professor Kranz, of the University of Louvain, who attended the summer meeting of the Iron and Steel Institute, at Dudley, last year, an interesting pamphlet, entitled, "Quelques jours sur le sol Anglais," 8vo., 1872, Peeters, Louvain, which also appeared in the *Revue Catholique*, in which he describes, in a pleasant manner, his experiences of the meeting, and other subjects connected with the coal and iron industries of England.

CANADA.—A notice of the deposits of titaniferous iron ores in Canada was given in the report for the third quarter of last year, since which, they appear to have also attracted attention on this side of the Atlantic; an English company, called the Canadian Titanic Iron Company, Limited, with a capital of £75,000, having been recently brought out for working the so-called "Saint Urbaine Titanic Iron Mountain lode, situated on the River Gouffre, near Bay St. Pauls, about 60 miles below Quebec, where a practically inexhaustible supply of such ore is said to occur.

The data upon which the prospects of the company are based, as shown in the prospectus, both as regards cost of ore and system, and cost of smelting in Canada, are, however, so opposed to all experience in the actual working of such ores, as well in Canada as in Norway, Sweden, and England, that it seems difficult to account for the great discrepancy.

FRANCE.—The general state of the iron trade in France has

during the last quarter been much more favourable, notwithstanding that the ironworks of the central and southern districts remain in nearly the same condition as before, many of them being in partial idleness, owing to want of means of transport; complaints on this head are, however, becoming less frequent in the other districts, more rolling stock being obtainable, and orders more abundant. In the Department du Nord there is now considerable animation, and a very sensible improvement has also taken place in the basins of the Meuse and Moselle.

At Hautmont a new company, under the style of Michel, Helson, and Co., has been formed for making pig iron, with capital said to have been principally obtained in Belgium. The works of the Société Gustave Dumont, now nearly completed, are said to be upon a scale sufficient to turn out 1,000 tons of plates per month.

A serious accident is reported as having happened on New Year's Day, to the blast furnace No. 1, at the Creuzot Iron Works; about ten tons of molten iron got through, or under, the bottom stone of the furnace, into the cross channels below, and as these unfortunately happened to be full of water at the time, a terriffic explosion took place, by which several lives were lost, and the furnace itself destroyed.

The bulletin of the *Comité des Forges de France*, which was stopped in August, 1870, on account of the war, has reappeared, and from a statement in it, it appears that the total importations into France were as follows, in tons:—

Ores.		Cast Iron.		Bars and Plates.	
1870.	1869.	1870.	1869.	1870.	1869.
485,005 ...	592,179 ...	115,235 ...	139,113 ...	66,746 ...	76,176

An elaborate memoir on the iron ores of the Departement de la Meurthe, by M. Braconnier, is published in abstract in the *Annales des Mines*, series vi., vol. xix., pp. 430-443, and contains full details of the occurrence, exploration, and chemical composition of the ores of this important district, which pertain chiefly to the oolitic formation, and of which 425,091 tons were raised in 1869.

Germany.—The official statistics of the mining and metallurgical industries of Prussia have now been published for the year 1870 in the Zeitsch. f. d. Berg Huetten u. Salin. Wesen i. d. Preussische Staate; from which we are enabled to give the following data:—

PRODUCTION OF IRON ORE.

	No. of Mines.	Workmen.	Production. In Zoll. Centners.	Production. In English Tons.
Private	1,040	22,165	51,831,993	2,550,309
Government	25	1,269	1,696,015	83,368
Total in 1870	1,065	22,902	53,528,008	2,633,677
,, 1869	1,167	25,190	57,911,389	2,847,110
Decrease	102	2,288	4,383,381	296,801

If arranged geographically, these quantities stand as follows :—

Mining Districts.	Mines.	Workmen.	Zoll. Centners.
Breslau (Silesia)	86	3,440	8,841,499
Halle (Prussian Saxony)	12	98	133,698
Dortmund (Westphalia, Hanover, Rhine)	51	2,882	10,312,663
Bonn (Westphalia, Rhine, Hohenzollern, Hesse-Nassau, Waldeck)	864	15,787	30,117,387
Clausthal (Hanover, Hesse-Nassau)	52	755	4,122,770
	1,065	22,902	53,528,008

And if classified according to the mineralogical nature of the ores :

	1870, Zoll. centner.	1869, Zoll. centner.	Increase.	Decrease.
Bog iron ore	847,216	798,744	48,472	—
Brown hematite	21,607,982	24,733,659	—	3,125,677
Spathic carbonate	10,631,549	11,149,117	—	517,568
Clay ironstones	951,442	1,212,212	—	260,770
Blackband	5,347,362	6,358,884	—	1,011,482
Redhematite (with a little yellow)	10,234,127	10,450,092	—	215,965
Magnetic iron ore	191,384	201,709	—	10,325
Limonite (Bohnerz)	3,716,946	3,007,012	709,934	—
	53,528,008	57,911,398		4,383,381

Reviewing the quantities of iron ore extracted from the Prussian mines, along with the number of mines in work, and workmen employed annually during the four years from 1867 to 1870 inclusive, they are as follows :—

	Mines worked.	Men employed.	Iron ore extracted.
1867	1,405	23,094	2,347,373 English tons.
1868	1,228	23,997	2,669,691 ,,
1869	1,167	25,190	2,847,110 ,,
1870	1,065	22,902	2,633,637 ,,

The falling off in 1870, as compared with the preceding year, is not in any way connected with the poverty of the mines themselves, but is altogether due to the great number of workmen taken away to the war with France.

With respect to the yield of the blast furnaces in the Prussian provinces, for 1870, we find that the total make of cast iron of all kinds amounted to 23,111,823 Zoll. centners, or 1,137,448 English tons, showing a decrease of 14,497 tons when compared with the preceding year, the total make in 1869 being 1,151,945 tons, and in 1868, 1,036,713 tons. The details of the production of cast iron from the blast furnaces, in 1870, are as follows :—

A. ORDINARY PIG IRON.

District.	Furnaces In blast.	Idle.	Workmen.	Smelted by Coke.	Charcoal.	Coke and Charcoal.	Total. Zoll Centners.
Breslau	35	53	3,599	4,507,744	234,284	——	4,752,642
Halle	2	—	28	——	23,986	——	23,986
Dortmund	22	48	3,947	7,219,992	5,749	9,586	7,235,327
Bonn	77	84	3,106	5,497,551	468,301	672,783	6,638,635
Clausthal	7	6	713	984,263	44,264	——	1,028,527
	143	191	11,395	18,209,550	787,198	682,369	19,679,117

B. STEEL IRON.

District.	Furnaces In blast.	Idle.	Workmen.	Coke.	Charcoal.	Coke and Charcoal.	Total.
Dortmund	2	5	630	904,754	——	——	904,754
Bonn	10	11	813	1,753,213	21,400	20,000	1,794,613
Clausthal	5	5	74	——	86,785	3,173	89,958
	17	21	1,517	2,657,967	108,185	23,173	2,789,325

C. CASTINGS DIRECT FROM BLAST FURNACE.

District.	Furnaces In blast.	Idle.	Workmen.	Coke.	Charcoal.	Coke and Charcoal.	Total.
Breslau	19	8	593	8,484	185,281	——	193,765
Halle	2	2	225	——	34,094	——	34,094
Dortmund	11	6	144	144,086	34,033	——	178,119
Bonn	23	15	1,119	3,374	216,196	——	219,570
Clausthal	3	2	172	——	17,883	——	17,883
	58	33	2,253	15,594	487,437	——	643,381

Although the make of cast iron in 1870 shows a small diminution as compared to that of the preceding year, it is the reverse with the production of wrought iron, which had increased by 9,550 tons, notwithstanding the unfortunate position of this manufacture, owing to the war. The total production of wrought iron, of all kinds, amounted in 1870 to 15,121,857 Zoll. centners, or 756,092 English tons, whilst in 1869 it was 747,542 tons, and in 1868 only 605,831 tons. The particulars of the make in 1871 are stated below :—

District.	Bar.	Sheet.	Wire.	Total.	
Breslau	3,067,163	66,537	104,526	3,238,226	Zoll. Centners.
Halle	245,421	23,050	140	268,611	,,
Dortmund	5,415,057	671,897	453,293	5,540,247	,,
Bonn	3,778,471	892,724	285,879	4,957,074	,,
Clausthal	51,892	65,724	83	117,699	,,
	12,558,004	1,719,932	843,921	15,121,857	,,

The statistics given of the steel manufactured in the Prussian provinces, during the year 1870, are as follows:—

District.	Ordinary.	Cast (and Bessemer.)	Refined.	Total.	
Breslau	6,890	——	3,442	10,332	Zoll. Centners.
Halle	76	18,835	——	18,911	,,
Dortmund...	387,416	2,323,237	61,840	2,772,493	,,
Bonn	230,752	67,668	39,064	337,484	,,
Clausthal ...	16,622	674	1,514	18,810	,,
	641,756	2,410,414	105,860	3,158,030	,,

These figures also show that, notwithstanding the unfavourable circumstances of 1870, the total quantity of steel of all sorts manufactured in that year was about 8,404 tons more than in the preceding year; the make of steel in the Prussian provinces being annually as follows:—

	Ordinary Zoll. Centners.	Cast (and Bessemer) Zoll. Centners.	Refined. Zoll. Centners.	Total Zoll. Centners.	Total English Tons.
1870.........	641,756	2,410,414	105,860	3,158,030	155,422
1869.........	792,252	2,055,444	139,623	2,987,319	147,018
1868.........	583,029	1,764,390	99,735	2,447,154	119,437

The new steel works, erected by the Rhine Steel Company, are already in operation, although they will not be completed for some months to come; they are on a scale calculated to turn out 20,000 tons per annum of Bessemer steel, in the form of rails, tyres, axles, artillery, &c.

According to the report of the Bochum Cast Steel Manufacturing Company, it appears that during the last quarter no less than 3,000 men were employed at the company's steel works, exclusive of 400 in their collieries, and notwithstanding the evil influence of the late war, the value of their cast steel production of last year (1871) is estimated at about £550,000.

A statement made in the Deutsche Indus. Zeitg. 1871, No. 29, shows that the German steel production has increased during the last 10 years, *i.e.*, from 1860 to 1870, in quantity, in the ratio of 1 to 6·37; in value as 1 to 5·61, and in number of hands employed as 1 to 3·21. Whilst in 1860, the 167 steel works in operation employed 3,915 workmen, and produced 25,312 metrical tons of steel, valued approximately at £577,000, the number of establishments in 1869 had increased to 206 with 12,578 hands, and a production of 161,319 metrical tons of steel, estimated as worth £3,242,700.

In the Oesterreich. Zeitsch. f Berg u. Huetten., 1871, No. 31,

p. 294, the following statistical statement is given for the German steel trade for the ten years from 1860 to 1869:—

Year.	Works.	Workmen.	Metrical tons.	Value.
1860	167	3,915	25,312	£577,000
1861	167	4,938	34,259	784,588
1862	185	6,161	40,916	883,132
1863	177	9,482	54,250	1,104,802
1864	170	10,756	71,354	1,733,000
1865	169	12,947	99,543	2,328,443
1866	215	12,821	114,433	2,758,950
1867	214	12,201	122,541	2,773,705
1868	203	11,415	122,837	2,745,049
1869	206	12,578	161,319	3,242,700

Some idea of the great rise in prices of iron ores and cast and wrought iron of every description, in Rhenish Prussia, may be formed from the following figures, which show the current prices per English ton at respectively the commencement and the end of last year:—

	£ s. d.	£ s. d.
Specular iron ore	1 1 10	1 7 0
Red hematite (45 per cent. iron)	0 11 5	0 14 5
Brown do.	0 14 8	0 19 2
Spathic carbonate	0 17 5	1 4 0
Bessemer pig	4 17 6	6 3 0
Grey foundry pig	4 10 0	5 17 0
White forge pig	4 8 6	5 12 6
Ima spiegeleisen	5 14 0	7 10 0
Inda do.	4 19 0	6 3 0
Hammered bars	10 16 0	12 0 0
Rolled do.	10 7 0	11 14 0
Ima sheet	12 12 0	15 0 0
Wire Rods	9 0 0	11 2 0
Flat bars	9 6 0	11 2 0
Puddled bars	7 13 0	8 14 0

The ironmasters of Alsace and Lorraine are now beginning to understand that, so far from suffering by their annexation to the German Empire, as they anticipated, they will, on the contrary, benefit materially by the change of nationality, for they now find the German market to be a much better one for their products than the French has been hitherto. As an example of this, it may be mentioned that the firm of Wendel, at Hayange, obtained in December the contract for supplying the Royal Railway at Saarebruck with 7,025 tons of rails at £8 15s., a price which was no less than twenty-nine shillings per ton below the lowest tender sent in from any of the German ironmasters; it is, therefore, probable that

we shall hear no more about their determination to rebuild their works on the French side of the frontier.

To the German literature of iron may be added :—

Grundriss der Eisenhuettenkunde. (Elements of Iron Smelting). Von Dr. H. Wedding, 1871. 8vo, with 205 woodcuts and 2 plates. Ernst & Korn, Berlin.

Uebersicht der Eisen-Industrie, und des Eisenverkehr Deutschlands, in den Jahren 1860 bis 1869. (Review of the German iron industry and trade from 1860 to 1869.) Von Dr. A. Frantz, 1871. Baumgaertner, Leipzig.

Die Hochofen Dimensionen als Grundlage des Hochofen Processes. (The dimensions of the blast furnace as a basis for the blast furnace process). Von O. von Hingenau.

INDIA.—As a proof of the antiquity of iron smelting in India, and also of the large forgings in wrought iron which could be executed by a people who now appear to have entirely lost the art, Mr. Mallet has directed attention to a wrought iron pillar situated at the Mosque of the Kutub, near Delhi, which must be more than one thousand, and may be as old as fifteen hundred years, yet is as large as the screw-shaft of some of our largest steamships; that part of the column above the present level of the soil being 48 feet high, with a diameter of 16·4 inches at the base, and 12 inches at the top immediately below the elaborately chiselled capital. It is calculated to contain about 80 cubic feet of iron, and to weigh not less than seventeen tons.

Mr. James Ferguson, in his illustrations of ancient architecture in Hindostan, also states that, in the Temple of Kanaruc, in the Madras presidency, which is estimated to date some time between the 11th and 14th centuries, beams of wrought iron have been used for supporting lintels, which are 21 feet long, and 8 inches square, and consequently would weigh more than 10 tons, so that we have instances occurring in parts of India, very distant from one another as well as representing totally different historical epochs, which prove the existence of the wrought iron manufacture, on a scale which allowed of the making of such immense forgings, as well as of the use of wrought iron as a building material on the large scale. It is also curious to notice, that nowhere in Hindostan does the use of cast iron, or iron castings of any kind, appear to have been general, if at all known, and that all the Indian processes for smelting iron which we are acquainted with, are based on the production of wrought iron, *i.e.*, iron in its malleable condition, direct from the ore, without its having passed through the intermediate stage of cast iron. In the report

of the travels of the native emissary of the Indian Government, in Central Asia, as published in the *Times* of Dec. 4th, 1871, it is however incidentally mentioned that "at Faizabad, the capital of Budukshan, he found the inhabitants skilful in smelting iron, and they send cast iron pots, pans, ornamented lamps, &c., to the market." It is also well known that the Chinese are extremely skilful in founding iron; some of their castings being so thin, as in this respect at least, to excel European productions.

Since the discovery, and successful working, of the coal fields in the Chanda District of Madras, a result entirely due to the persevering exertions of Major C. B. Lucie Smith, and which cannot but prove of incalculable importance to the future of this portion of Hindostan, this officer has directed the attention of the Government of India to the subject of utilising the numerous deposits of extremely rich iron ores, which are largely diffused over the whole district (the extreme west excepted), and which at present are only worked on an extremely insignificant scale by the natives, in small clay furnaces, in the primitive manner described by Mr. Mark Fryar, in a letter to the *Mining Journal*, some time back. The iron and steel (so well known under the name of Wootz) thus extracted from the ore, are probably not to be surpassed in quality, but the process is not only extremely rude and costly, but also very destructive to the forests, owing to the enormous quantity of charcoal required to make a ton of the iron. According to the native smelters, the quality of the product is much dependent upon the nature of the charcoal employed, that from Teak being considered the best, then the Mohwa wood charcoal; but, as at present, the forest regulations do not allow either of these trees to be used as fuel, Khair wood is now generally employed. Should it be a question, however, of establishing the manufacture of iron in this district on a large scale, the supply of fuel to reduce the ore, must, as a matter of course, be derived from the newly-discovered coal deposits. In the carboniferous strata of this district, beds of ironstone are found, but the ores hitherto worked are the rich, and almost chemically pure native oxides of iron, which occur especially at Lohara, Tatolee, and Wugurpet, to the west of the river Wyngunga, and near Dewulgaon, Ambagurh Chowkee, and Pawee Moolanda, on the east of the same river.

Samples of these ores were placed in the hands of the author of

this report by Major Lucie Smith, acting for the India Government, for the purpose of examining as to whether they would be suitable for smelting in coke blast furnaces, and to test the qualities of the ores themselves; the following results will show the great purity of the three samples submitted to chemical analysis:—

	Lohara.	Dewulgaon.	Goonjwai.
Iron, metallic	69·208	70·006	70·134
Oxygen in combination	29·376	28·670	28·739
Sesquioxide of Manganese	0·090	0·084	0·108
Silica	0·823	0·813	0·545
Alumina	0·432	0·387	0·396
Lime	0·054	0·026	0·055
Magnesia...	trace	trace	trace
Sulphur	0·012	0·013	0·020
Phosphorus	0·005	0·001	0·003
	100·000	100·000	100·000

All these ores were compact admixtures of the native magnetic oxide of iron, with more or less specular oxide (or crystallised hematite) and equal in quality to the finest Swedish iron ores, so that there can be no question as to their suitability for producing the very finest iron or steel, when smelted with charcoal or with coke, provided the coal of the Chanda basin is of sufficiently good quality.

Italy.—According to statistical tables, published in vol. 29 of Revue Universelle des Mines, for 1871, it would appear that the total average amount of pig iron produced per annum in Italy, during the four years 1867 to 1870, inclusive, amounted only to 11,000 tons, nearly the whole of which is converted into wrought iron; this quantity was produced by 16 charcoal blast furnaces, in which, on an average, 22,500 tons of iron ore were smelted annually, and all of which are situated in Lombardy, with the exception of three in Tuscany, and two in the valley of Aosta.

During the same four years, an average of 32,505 tons of iron was annually exported, almost entirely to France, and, in greater part, from the celebrated mines of Elba. During the years 1862–3, the exportation of iron ore from Elba reached 50,000 tons per annum, and would, no doubt, have very largely increased, instead of diminishing, had not the opening of the great Algerian iron mines, where there was an excellent port of shipment for the ore at Bonn, diverted the trade to that place from Elba, where no such advantages existed.

The cast and wrought iron, as well as the steel from Lombardy, particularly those from the works at Lovère, are very superior, and can compete with the Swedish in quality.

We have not been able to test the accuracy of the above statistical dàta by direct reference to Italian official sources, but would, nevertheless, point out that the figures do not seem in accordance with those contained in a report by M. Defly, the French consul at Turin, to his foreign ministry, dated 29th March, 1869, and which is published in the Annales des Mines for that year, series VI., vol. XVI., pp. 600–627, in which, amongst other statements, it is reported, that the number of blast furnaces in Italy amounts to thirty-eight, producing, annually, 22,000 tons of iron ore, or double the estimate published in the Revue Universelle.

A description of Krupp's great steel works, at Essen, in Rhenish Prussia, by G. B. Pirelli, will be found in the numbers of Il Politechnico for October, November, and December, 1871; and a pamphlet on the manufacture of iron in Lombardy has also appeared, entitled Della lavorazione del ferro nelle Valli Lombardi. Milan. Ràpetti e Bellini l. 1.50c. A new monthly periodical, devoted to all branches of industrial science, entitled L'Industriale, commenced the publication of its first number, in Milan, in January, 1871; in the December issue, we find an article on the forthcoming general meeting of the Iron and Steel Institute, in London, and whilst we hope that some of the Italian ironmasters may also attend the meeting, we have to thank the editors of L'Industriale for directing attention to the general invitation issued by the Council of the Institute.

JAPAN.—We have, as yet, not had any opportunity of alluding to the iron or steel industry of this remote country, notwithstanding that it is well known that some of their iron and steel manufactures are entitled to much praise. The only piece of information we have come across connected with the actual state of iron making in Japan, is to be found in an article in Les Mondes, t. XXVI. for December, 1871, written by M. Sévoz, a mining engineer resident in Japan, who, in describing the mode of iron smelting in the mining district of Ykouno, states it to be a modification of the Catalan system of the South of France and North of Spain, in which wrought iron is produced direct from the ore; the distinguishing feature, in Japan, being, that instead of treating from 700 to 1,000

lbs. of iron ore at a time, as in the Pyrenees, no less than 3,200 lbs. is put into the furnace at once, from which an immense bloom weighing above 1,300 lbs., is obtained, which is then subjected to the action of a large hammer, constructed somewhat like a pile-driving ram, to which motion is communicated by a tread wheel, about 36 feet in diameter, driven by men's feet.

NEW ZEALAND.—In our last quarterly report, it was stated that the general government of New Zealand had ordered new experiments to be made with the Taranaki titaniferous iron sand, to settle definitely the best mode of working it, and we now learn from a correspondent of the *Times* that these experiments have resulted in proving that steel of the highest quality can be produced at a *minimum* cost by a most simple process. The iron sand, as taken from the beach, is mixed with an equal quantity of clay and of the ordinary sea sand, which contains a large admixture of shell; these materials are worked up into bricks, which are hardened in a kiln, broken up into irregular pieces, and smelted in an ordinary cupola furnace. The product of this simple process is cast steel of the finest possible texture, from which some beautiful specimens of the finest cutlery have been manufactured. These experiments were conducted by a mechanic in the government employ, who was restricted to an expenditure of £100, and was, therefore, only able to erect a furnace of the most temporary description; he, however, succeeded in producing, at the first and only trial, 5 cwt. of steel in the manner described above, and his success seems likely to lead to further and more extensive efforts to utilise the almost inexhaustible deposits of this ore which exist at Taranaki and elsewhere. A perusal of this report will be sufficient to convince any one conversant with the subject, that in New Zealand, at least, more confidence is still placed in the blundering old rule of thumb, than in the teaching of metallurgy as an applied science.

SPAIN.—The official statistics of this country are, like most other things connected with Spain, always very far behind date, and the latest data, connected with the iron mines and smelting establishments, for which we have to thank Messrs. Basterrechea y Rodriguez, of Bilbao, have but recently appeared in print, and only bring us down to 1869—in which year 277 iron mines are reported to have been in operation, employing in all, 3,003 hands, and producing 311,343 tons of iron ore; of which quantity the

largest amount came from the province of Biscay, which figures for 164,800 tons, after which, that of Santander stands for 34,538 tons.

The total make of cast iron in Spain, 1869, is given at 34,486 tons, and that of wrought iron at 35,626 tons, both of which were principally from the ironworks of the provinces of Biscay and the Asturias.

The production for the four preceding years is given, in tons, as under:—

	1864.	1865.	1866.	1867.	1868.
Iron ore	253,121 ...	191,684 ...	180,131 ...	254,481 ...	385,553
Cast iron	50,776 ...	49,533 ..	39,260 ...	41,934 ...	43,162
Wrought iron ...	44,565 ...	42,298 ...	32,338 ...	39,825 ...	39,897
Steel	201 ...	301 ...	577 ...	331 ...	369

In 1870, and more especially last year, the iron mines of the north of Spain began to attract much attention, and to be explored on a vastly greater scale than previously, owing to the augmented demand, and higher price paid for richer and purer iron ores for exportation to England, to be employed in the manufacture of cast iron, suitable for conversion into steel by the Bessemer process; and recently, in the vicinity of Bilbao alone, concessions for making no less than eleven branch railroads have been granted by the Spanish Government, for the transport of iron ores from the mines to the shipping places.

A very large supply of excellent and rich iron ores, chiefly hydrous red, brown, and yellow hematites, and spathic carbonate of iron, can be obtained from this part of Spain; but, at present, the exportation of such ores has been limited by the want of means of transport, and of appliances for loading the ships, as well as the small depth of water in the river, and over the bar at the mouth of the river of Bilbao. Several large English companies have already been formed for the exploration of some of these iron mines, and the shipment of the ores for England; one or two of which also propose erecting blast furnaces on the spot to smelt the ore with coke from England, so as to secure cargoes for the shipping both ways. In the course of another year we may, therefore, expect to see the exportations of iron ore from the north of Spain immensely increased.

From an examination of the principal mines of this part of Spain, made last autumn, by the author of this report, it appeared that all these deposits of iron ore occur in the cretaceous formation

traversing it in the form of great lodes or veins, sometimes as much as from one to three hundred feet wide, which, although frequently more or less coincident with the strike of the stratification of the beds of limestone, shales, or sandstones which form "the country," do not always follow the dip or underlay of the beds in depth, and, at places, diverge and break through the sedimentary strata. The upper portion of these deposits, for a few feet, to even a hundred or more feet downwards from the surface, consists of hydrated oxides of iron, of a red, brown, or yellow colour, free, or very nearly free, from sulphur or phosphorus; at greater depths, however, they invariably change into white or grey spathic carbonate of iron (sometimes containing specks of pyrites), which is the original mineral from which, by atmospheric agencies, the oxidised iron ores, previously mentioned as forming the more superficial portion of the deposits, have been formed. Since the spathic iron ore is infinitely harder and more expensive to work, besides not containing more than from 40 to 45 per cent. of metallic iron, the workings hitherto have, in all the mines, been confined to the extraction of the richer oxidised surface ores, which contain from 50 to 60 per cent. iron, and require little or no blasting. Eventually, however, as the mines get deeper, the spathose ore must become the staple of exportation, and as it can be brought up to a percentage of about 60 per cent. metallic iron by calcination, it will probably be found more advantageous to roast these ores on the spot, previous to shipment.

Attention has also been directed to working the rich magnetic iron ores which are found abundantly in the South of Spain; amongst others, the extensive outcrop of iron ore at Marbella, about midway between Gibraltar and Malaga; this is a compact magnetic oxide of iron, containing an average of about 60 per cent. metallic iron, with, according to some analyses, a little titanic acid; an English company has also been formed to work these mines, and according to their published estimate, they are able to sell this iron ore, delivered in England, with advantage to themselves, at a price of 24s. per ton, which is a very low price, if the distance be considered.

SWEDEN.—From the official report of the Swedish Chamber of Commerce, it will be seen that, during the year 1870, some 463 iron mines were in operation, employing 4,531 workmen, and pro-

ducing 604,511 English tons of ore, in addition to 13,476 tons of lake ore, a hydrous oxide of iron or limonite, which is found as a deposit at the bottom of shallow lakes, from which it is dredged up; this peculiar ore is formed by the action of miscroscopic organisms, which extract the iron from the water in which it is held in chemical solution; the bottoms of these lakes pertain to different owners, and are divided into sections, which are alternately dredged after an interval of some years' repose, during which the iron ore again accumulates.

The total number of charcoal blast furnaces in Sweden, in 1870, was 301, of which 88 remained idle, and 213 were in blast, during a total of 37,896 days (of 24 hours each), in which they yielded 294,319 English tons of cast iron, which is the greatest quantity of iron ever recorded to have been made in Sweden in any one year.

If the average number of days (of 24 hours each) in blast, and quantity of iron turned out per blast furnaces in operation in the whole kingdom, in 1870, be calculated out, it will be found to be 178 days, and 1,549 tons, whilst in the previous year, 1869, it was, respectively, 188 days, and 1,439 tons of cast iron.

The largest annual yield of any one charcoal blast furnace in 1870 was 4,729 tons which was at Langshyttan, in Kopparbergs, Laen.

The total number of hands employed in the Swedish ironworks in 1870 was 14,873, and the following figures show a comparative statement in English tons of the total Swedish production of iron ore, cast and wrought iron, and steel for the five years from 1866 to 1870 inclusive:—

	1866.	1867.	1868.	1869.	1870.
Iron ore from mines.....	473,586	475,076	524,768	580,027	604,511
Ditto from lakes.....	7,996	17,434	11,007	6,134	13,476
Cast iron.....................	225,619	248,522	257,884	286,356	294,319
Wrought iron.............	163,499	167,098	168,617	176,068	189,972
Steel and other irons....	22,889	22,413	25,202	31,304	32,343

Under the last head for 1870 is included the first quantity of iron and steel rails made in Sweden, this manufacture having only been recently introduced, and in 1870 only reached 609 tons in all, of which 134 tons were iron rails made at the new Smedjebacken Rolling Mills, and the remaining 475 tons steel rails rolled at the Motala establishment. Under this head, also, is comprised the entire Swedish steel production for 1870, which amounted to 11,939

tons, of which 156,054·45 centners Swedish, or about 6,502 English tons, were made by the Bessemer process at the following works:—

Sandviken,	in	Gelfeborgs,	Laen	...	76,071·00 centners.
Lenna	„	Upsala	„	...	1,036·40 „
Siljanfors	„	Kopparbergs	„	...	4,616·48 „
Baecka	„	„	„	...	23,952·61 „
Fredshammer	„	„	„	...	9,615·40 „
Vestanfors	„	Vestmanlands	„	...	40,349·40 „
Carlsdal	„	Oerebro	„	...	413·16 „
(About 6,502 English tons.)			Total	...	156,054·45 „

The manufacture of Bessemer steel in Sweden is now extending rapidly. New works have been erected at Abæckshyttan, Svartnaess, Iggesund, and Forssbacka, and various other establishments are projected. A quantity of Bessemer steel, made from Dannemora iron, has been sent as a trial to England from Lenna, in the form of small ingots, weighing about 60lbs. each, in the hopes that it may be found equal in quality to crucible cast steel; as yet, however, the results are not known.

From the Custom House books, it appears that, in 1870, 308,618 centners, or about 12,860 English tons of iron ore were exported from Sweden, and that for the five years from 1866 to 1870 inclusive, the exportation of iron and steel, of all kinds, was as follows, in English tons:—

	1866.	1867.	1868.	1869.	1870.
Charcoal pig	14,864 ...	23,155 ...	20,418 ...	20,119 ...	39,150
„ bar	109,889 ...	134,946 ...	110,235 ...	114,792 ...	117,663
Steel and other iron ...	7,084 ...	11,733 ...	14,298 ...	13,481 ...	13,332
Total	131,837	169,834	144,951	148,392	170,145

United States.—On the 17th October last, a meeting of the Eastern Ironmasters' Association, which comprises representatives of all the ironworks in the Atlantic States, was held at the Astor House, New York, and was fully attended, most of the mills being represented. The annual election of officers took place, Mr. James A. Burden, of Troy, in New York, being appointed president; Messrs. James E. Walker, of Troy, and Nathan Rowland, of Philadelphia, vice-presidents; and Mr. W. E. S. Baker, secretary. The

schedule of prices for extra sizes and lengths, recommended in the May meeting, was adopted, with some modifications, to meet the present state of affairs, as also the decimal system of selling iron.

The Report of the United States Bureau of Statistics shows that from the commencement of 1870, during the eleven months ending May 31st, 1871, the latest issue received, the United States imported 156,576 tons of pig iron, being an increase of 5,000 tons over that received during the same period in 1869–70; of rails and other railway iron, the total importation was 437,687 tons, or nearly double; of scrap and old iron, which includes old rails, many of which, to the detriment of the revenue, are *not so old* as to require re-manufacturing, 139,741 tons, or a slight increase on the previous return; of steel, including ingots, bars, sheet, and wire, the value is returned at £691,731, or an increase of about £200,000. In the three items of pig, railroad, and scrap or old iron, the total value of the importations for the eleven months ending May 31, 1871, are set down at £4,142,920, against £2,684,295 in the corresponding period ending May 31, 1870, or an increase of no less than £1,458,625. The exportation of iron, of all kinds, from the United States during this period, did not reach a total of 4,000 tons, and was even less than in the previous year.

The iron trade on the whole is going on very favourably, with some few exceptions only; the last advices from Cincinnati state that most of the works stood still, in consequence of the supplies of raw materials being cut off, first by the low state of water in the Ohio, and subsequently by the freezing over of that river.

At Sharpsburg, in Pennsylvania, two blast furnaces, said to be the largest as yet erected in the United States, were about to be blown in, and if successful, were to be followed by the immediate erection of two others of like size. The new ironworks at Edgehill, in the same neighbourhood, were also about to commence operations, and a new rolling mill, at Easton, is being started by Messrs. Oliver & Co., as also a new blast furnace at Centreville, in the same State. It is also reported that the Southern Pennsylvanian Iron and Railroad Company, in conjunction with the Reading Railroad Company, are about to erect ten new furnaces on the line of the Schuykill Navigation.

The Valley Iron Company are making arrangements for the manufacture of steel-headed rails; and in Indiana, the New Albany

Rolling Mill, which was destroyed by fire a few months ago, is now rebuilt entirely in iron, and is already in active operation.

The largest wire rope manufactory in the United States is that of Messrs. John A. Rœbling & Sons, at Trenton, New Jersey, which was first established, in 1849, by the late John A. Rœbling, and now covers 10 acres, employing 125 hands, along with three steam engines of an aggregate power of 350 horses; the rolling mill is capable of turning out forty tons per week.

As a curiosity, it may be mentioned that the Robinson and Rea Iron Works, at Pittsburg, have recently melted down about 100 tons of old British cannon, which were used in the war of 1812, the metal from which is of very superior quality.

The following notice of a new furnace, in the Lake Superior district, is extracted from the Marquette Mining Journal:—"The Bay furnace stands on a lot of 19,000 acres hard wood forest, at the western entrance of Grand Island harbour. Ground for the furnace was first broken on the 19th July, 1869, and the first casting was made on the 28th February, 1870; the furnace has been again blown in, August 29, 1871, with a stock of 75,000 bushels of charcoal, and is now making 16 tons pig per day, with a consumption of 100 bushels to the ton. The whole make of the furnace, so far, is about 6,000 tons. The diameter at the boshes is 9 feet, or same as in the Champion and Schoolcraft furnaces, but it is 2 feet higher; the hot blast apparatus contains 27 pipes, and is placed at the top of the furnace, the blast pipe being carried down outside, instead of built into the stack, which is considered a decided improvement, and is to be also carried out at the new peat furnace at Ishpeming. No cold air reservoir is used, the blast taken direct from the (2) cylinders is found to be steady and uniform. The coal and ore are hoisted up by a water balance; the calcining kilns are all of the beehive pattern, and hold 40 cords of wood each; there are four sets of kilns, two of them containing eight kilns each, are situated two miles from the furnace, and the others about $3\frac{3}{4}$ miles distant.

In the proceedings of the Lyceum of Natural History of New York, vol. I., pp. 51-61, Dr. S. Martin has described the so called steel ore or Codorus ore of Pennsylvania, which is largely employed at York, Pa., in the production of cast steel; it has a schistose appearance, and contains about 40 per cent. of magnetic oxide of

iron, with 10 per cent. iron glance with a little chromium, but no phosphorus or sulphur, except in some specimens in which an admixture of cobaltiferous iron pyrites, brochantite, &c., were visible.

A paper on the Titaniferous iron belt, near Greensboro', in North Carolina, by J. P. Lesley, is to be found in the proceedings of the American Philosophical Society, vol. XII., No. 86, pp. 139-158, which contains a very full account, illustrated by woodcuts, of these large deposits, as well as some remarks on the utilization of similar ores in other parts of the world.

It is reported that the large deposits of iron ore at Mount Washington are about to be worked by a Company recently formed in Glasgow, Mr. Archibald Baird, the manager of the Quarter Iron Works, Glasgow, having arrived in the United States to take the entire management, whilst Mr. William Rennie, of the same place, is to follow in the capacity of general manager.

B. METALLURGICAL TECHNOLOGY.

Effects of Severe Cold on Cast Iron.—An instance of the effects of the exposure for some hours to a low temperature, on iron castings, is recorded by H. Cock, in "Les Mondes," for January 11th, 1872. This took place on the night between the 8th and 9th of December last, during a cold of 5° Farenheit (37°F. below the freezing point), when the cast iron framework of a 12 horse-power horizontal high pressure steam engine, employed in the printing works of MM. Renow and Maulde, in Paris, broke suddenly in three different places at the moment of starting the engine. A parallel case might be added from the experience of the author of this report, in which the cast iron crank of a 20 horse-power blowing engine, at the Espedal Works in Norway, which had worked several years smoothly, suddenly snapped in two at the moment of starting the engine during a most intense cold, when the thermometer indicated 33° Farenheit (66°F. below the freezing point), or only 7° below the freezing point of mercury.

Titanic Iron Sands.—A paper by Burkhart, in the Berggeist, vol. XVI., Nos. 27-30, describes the occurrence and composition of this class of iron ores, in various parts of the globe, more particularly referring to those of New Zealand and Canada.

CONCENTRATION OF IRON ORES BY MAGNETIC ACTION.—In the third quarterly report for last year, attention was directed to a machine patented for this purpose by Dr. Larue, of Quebec, which was specially intended for separating the particles of magnetic iron ore contained in the great deposits of ferruginous sand at Moisie, in the Gulf of St. Lawrence; since then, a similar machine, differing somewhat both in principle as well as construction, has been patented by Messrs. Balch and Nelson, of Montreal. In this machine the ferruginous sand is, after being sifted, allowed to flow from a hopper in a thin stream, so as to be acted upon by a series of electro-magnets attached to a revolving drum. The contact pieces, which connect the wires of the electro-magnets with the battery, are so arranged that although the magnets are excited during that portion of the revolution of the drum, during which they act upon the mixture of iron ore and sand, yet during the subsequent portion of their revolution they cease to be magnetized, and thus the particles of iron ore, which they have attracted and separated from the sand, either fall down by their own weight or can readily be removed by the use of a brush.

DEPHOSPHORIZING IRON ORES.—Jacobi's system of washing iron ores with a solution of sulphurous acid, in order to remove the phosphates contained in them, previous to smelting them in the blast furnace, which was noticed in the last quarterly report, has been since worked on the large scale at the Kladno Iron Works, and is reported upon as having been extremely successful; samples of the purified grey and white pig iron, and puddled bars, having been shown at the meeting of the German Engineer and Architect Association, on the 3rd November, at Prague, and pronounced unexceptionable. As previonsly remarked, however, it does not seem probable that the process can ever become one of general application, notwithstanding that, under special local circumstances, it may, as in the above instance, be successfully carried out.

KEEPING BLAST FURNACES ALIGHT.—An instance of how long a blast furnace may be kept in a dormant state without blowing out, occurred in the late Franco-German war. The new coke blast furnace, at Dillingen, on the river Saar, although situated only a few miles from the collieries which supply it with fuel, was, during the war, for some time entirely cut off from communicating with the coal mines, which were abandoned for the moment, and, con-

sequently experienced a total want of fuel. The Director, Mr. Siegers, determined to keep the furnace alive if possible, began at once to reduce the burden, diminishing the charge of iron ore to one-half, but keeping the proportion of coke as before; whilst quite full, the blast was cut off from the furnace, and the top and all other apertures closed as air-tight as possible, after which it was allowed to stand until a supply of fuel could be again procured, which was not until ninety days had passed; the tuyeres, hearth, and top were now opened, and the blast turned on, when, twelve hours later, the first clean cinder made its appearance, and the furnace itself soon came round to its usual working order.

Blast Furnace Lining.—At Prevoli, in Austria, serpentine has lately been tried for lining the coke blast furnaces, but was not found to answer, mainly on account of its want of compactness and uniformity in texture. Compared with fire-bricks, it was found that serpentine blocks, originally 24 inches, were in parts brought down to as little as 2 inches, whilst good fire-brick, of the same size, still remained from 6 to 8 inches thick. In Hungary, and some other countries, steatite has been in common and successful use for lining the charcoal blast furnaces, but it is doubtful whether it would stand in coke furnaces.

Chenot's System of Producing Iron and Steel direct from the Ore.—In the Revue hebdomadaire de Chimie Scientifique, for September 7th, 1871, M. C. Mène describes at some length this process, in which the iron ore, after a previous calcination, is reduced to the form of metallic sponge, in peculiarly arranged furnaces. If steel is to be produced, this sponge is saturated with coal tar, resin, or other suitable carbonaceous matter, and then heated, after which the carburetted sponge is ground to powder and strongly compressed in moulds, until it is formed into solid lumps, which are fused in crucibles as usual. The cast steel thus produced on the large scale at Clichy, is reported as being of excellent quality, but it is certainly open to doubt whether the phosphorus and sulphur are eliminated by this treatment, as is asserted. It is stated that this process is also in operation on the large scale at S. S. Ybarràs Iron Works, situated at the mouth of the river, near Bilbao, in Spain.

Spiegeleisen.—The importance of obtaining a supply of spiegeleisen for use in the conversion of cast iron into steel by the

Bessemer process was not fully appreciated by our steel manufacturers until the outbreak of the Franco-German war cut off, at least for a time, the supply of this article, which then had its principal seat of manufacture on the east bank of the Rhine, in Westphalia and Nassau. This circumstance led to the late successful attempt to make spiegeleisen at the Ebbw Vale Iron Works, and directed the attention of many other of the British steel manufacturers to this subject.

Several applications have consequently been made to the foreign secretary for information as to the process employed on the Continent for the manufacture of spiegeleisen, and for this reason it is proposed in the present pages to give a short resumé of what he has been enabled to learn during his recent visits to Germany and Sweden, notwithstanding that the information acquired is necessarily extremely incomplete, since this manufacture has been kept surrounded with an atmosphere of mystery and concealment as regards working details.

Spiegeleisen is at present made, on the large scale, in Germany, Russia, and Sweden, and curiously enough, the ores from which it is reduced are of extremely different and distinct characters in each of these countries. In Germany it is made entirely from the manganiferous spathic carbonate of iron; in Russia, as noticed in the third quarterly report of last year, it is reduced from ferruginous oxides of manganese; and in Sweden, it is produced by smelting a mixture of knebelite and manganiferous garnet, both of which minerals are compound silicates of iron and manganese. In one point, however, they all agree, which is, that in all these ores the oxides of manganese and iron, if not in actual combination as compound silicates or carbonates, are at any rate in a very intimate admixture with one another, and therein lies one of the most important points connected with this manufacture; for, it would appear, wherever true ores of manganese have been added to the usual charge of the blast furnace, in the expectation of obtaining spiegeleisen rich in manganese, that this has not succeeded, or at most, that only a small fraction of the manganese added has combined with the iron, the major part having been carried off in the slag; for which reason, when it is desired to produce a cast iron containing much manganese, it is requisite that this metal should be added to the charge in the shape of some strongly ferruginous compound,

thereby facilitating the process of reduction, since a mixture of the two oxides of manganese and iron is much more easily reduced to the metallic state and so enabled to unite with the iron from the rest of the charge than oxide of manganese alone, which, unless the heat is very intense, and the reducing action of the furnace nearly perfect, is extremely apt to go into the slag in the state of silicate, from which it subsequently cannot, or only with great difficulty, be recovered. The oxides of manganese are, it must be remembered, infinitely less easily reduced, and require more time as well as a much higher temperature than the oxides of iron, and from what has already been said, it will naturally follow that in making spiegeleisen particular attention should be paid to the following points:—

1. The mineral used as a source of manganese should be in itself highly charged with iron, so as to facilitate and ensure the reduction of as large an amount of the manganese contained in it as possible.

2. The charge of the furnace should be highly basic, or, in other words, an excess of limestone or, preferably, burnt lime should be used.

3. The working of the furnace should be much slower than is usual in iron smelting, in order to allow more time for the reduction of the oxides of manganese.

4. The temperature of the blast furnace should be as high as possible, using as hot a blast as can be obtained, and, as coke admits of the use of a sharper blast, and affords a greater heat, it is to be preferred to charcoal in this manufacture.

In Russia, the spiegeleisen produced at Nischne Tagilsk is smelted with charcoal, and is known for its good character; it is reduced from a mixture of the native oxides of iron, which in themselves contain some manganese with ferruginous Braunite, which contains about 40 per cent. metallic manganese, with 10 per cent. metallic iron, in intimate admixture.

In order to increase the amount of manganese in grey pig iron, which already contained 1·2 per cent. of manganese, so as to obtain a spiegeleisen, trials have been made at Wotkinski, by re-melting this pig iron in a cupola, with the addition of from 12 to 15 per cent. of clean native oxide of manganese (manganite or pyrolusite), which have resulted in making a spiegeleisen, containing between 5 and 6 per cent. metallic manganese.

In Sweden, spiegeleisen has been produced in several parts, but principally at Schisshyttan and Ramshyttan, in Darlecarlia, where, as mentioned in the third quarterly report for last year, it is obtained by smelting a mixture of knebelite and manganiferous garnet, which contains an average of about 42 per cent. iron with 13 per cent. manganese, in the blast furnace, (which is 47 feet high, and has two tuyeres) with as hot a blast as could be obtained from an iron pipe apparatus. The fuel employed is a mixture of half charcoal and half coke, and the ore is fluxed with 30 per cent. of its weight of limestone. The ore frequently contains visible specks of galena, pyrites, and zincblende, but it is stated that no sulphur is found in the spiegeleisen, although the slag which, when the furnace is working well, has a peculiar yellowish green colour, is said to contain 4 per cent. sulphur, and up to as much as 16 per cent. oxide of manganese.

The ordinary spiegeleisen obtained at Schisshyttan is superior to the general run of the German, and contains an average of 13 per cent. manganese, with about 4 per cent. of carbon, or 5 per cent. carbon, silicon, &c. Occasionally it has been as high as 17 per cent. Mr. Alexander Keiller, the manager of these works, informed the author that he was then producing some which averaged 15 per cent. manganese with only 2½ per cent. carbon, but that this metal was altogether different in appearance, and could not be made to assume the crystalline bladed reflecting fracture, peculiar to spiegeleisen, and from which its name is derived, and, in consequence, was regarded with prejudice in the market by the buyers, who judge from appearance alone. He also stated that he had latterly succeeded in producing a cast iron, containing as much as 23 per cent. of manganese, along with only 2 per cent. of carbon; such an alloy would be a considerable step in advance, as it would to a great extent overcome the objection to the employment of spiegeleisen, which from its containing a large percentage (4 to 5) of carbon, is less suited for the production of very soft qualities of Bessemer steel.

It appears when the quantity of manganese contained in a cast iron exceeds a certain point, that there is a tendency for the carbon to diminish in percentage, and, in writing to Mr. Henderson, of Glasgow, on that subject, he replied, "It is a well established fact, that in proportion to the increase of manganese in the alloys with iron, so the carbon decreases, so much so, that when you get

to 30 per cent. manganese, the carbon is down to 0·25 or 0·40 per cent."

In the Filipstad mining district, in Sweden, Bergmaster Sjoegren informed the author that numerous attempts to produce spiegeleisen, by adding the native oxides of manganese, particularly Hausmannite, which contains 72 per cent. metallic manganese, and occurs abundantly in that district, had failed, the iron so produced not containing more than about 4 per cent. of manganese, as the excess of that metal was invariably carried off in the blast furnace slag. We understood that a considerable quantity of Hausmannite had been exported to Sheffield from this part of Sweden in the course of last summer, for use in the steel manufactories there.

The German manufacture of spiegeleisen, which is by far the largest of all, is principally carried on in the northern part of Nassau, and the southern portion of Westphalia, and, as regards it, the author can add but little to the information contained in a report by Mr. J. Wiborg of his metallurgical journey to the Rhenish Provinces, made to the Iron Office in Sweden, and published in Jern Contorets Annaler for 1870, from which most of what follows is extracted. The ores used for the production of spiegeleisen are found in mineral lodes which traverse the Devonian geological formation on the eastern bank of the Rhine. They are the so-called spathic iron ores, which are carbonates of iron containing variable quantities of carbonate of manganese in intimate combination with one another. They usually contain more or less copper and iron pyrites, with, occasionally, traces of galena and zincblende, and more frequently a large admixture of quartz, which is picked out as cleanly as possible by hand after the ore has been roasted, when the quartz is more easily distinguished by the eye, since it remains white, whilst the iron ore has become reddish-brown through oxidation.

The following analyses show the chemical composition of the ores from three of the principal mines:—

	Stahlberg.	Kirschenbaum.	Huth.
Carbonate of iron	74·47	76·04	75·39
,, manganese	17·08	13·50	18·20
,, lime	1·34	1·13	1·50
,, magnesia	5·75	7·87	5·08
Insoluble matter	1·08	0·95	0·18
	99·72	99·49	100·35
Percentage of metallic iron	41·70	42·58	42·21
,, ,, manganese	8·16	6·46	8·70

Before being smelted, these ores are roasted in kilns from 18 to 20 feet high, with two grates, one above the other; they are filled with coke (small) and ore, using 8·4 cubic feet of the former to $2\frac{1}{2}$ tons of the latter, and lighting the whole from the lower grate. The ore in each kiln (about 7 tons) is raked out once a-day, through an aperture made by removing some of the upper grate bars. The object of this roasting, in which the ore loses about one-third its original weight, is to expel the carbonic acid from the ore and convert it into oxide; it also enables, as before-mentioned, the quartz mixed with the ore to be picked out by hand.

At the Lohe blast furnace, which belongs to the Cœln-Muesener Company, the fuel employed is either charcoal or coke alone, or more often a mixture of both. The charges employed are with charcoal alone, 1,035lbs. roasted ore, with 180lbs. limestone to each 30 cubic feet of charcoal, which is chiefly made from beach and oak woods; with coke alone, it is 2,197lbs. roasted ore, with 602lbs. limestone to each 42 cubic feet of coke; and with the mixture of charcoal and coke, the charge was 1,233lbs. roasted ore, with 360lbs. limestone to each $10\frac{1}{2}$ cubic feet of coke, mixed with 20 cubic feet of charcoal. As a rule, about 40 such charges would be run down in the twenty-four hours, or a total of about from 1,700 to 1,800 centners per week.

The dimensions of the blast furnace are as follows:—Total height, 42·4 feet; height from sole of hearth to tuyeres, 2·1 feet; height from sole to top of hearth, 4·3 feet; height from top of hearth to boshes, 9·6 feet, and thence to top of furnace, 28·5 feet. The diameter of the hearth, the sides of which were parallel, was 4·3 feet; diameter at boshes, 11·3 feet; and at top of furnace, 5·3 feet; the top being covered with a movable cover, which opens to admit the charge.

The temperature of the hot blast was lower than it ought to be, rarely exceeding 572° Fahrenheit; the blast is introduced into the furnace by three tuyeres, the diameter of which, and the pressure of blast, being varied according to the nature of the fuel made use of, being from 16·6 lines in diameter, and 16 lines mercurial pressure up to 21 lines diameter, with 22 lines pressure.

It is found by experience that the peculiar bladed texture of spiegeleisen depends more on the percentage of carbon than of the manganese, for with very high percentages of the latter, this

crystalline structure is not more, if as much, developed as with low percentages of that metal. This structure is also much better developed, if the iron, when tapped, be covered with slag, so as to allow it to cool more slowly, for which reason it is usual to let a considerable quantity of slag accumulate in the furnace, so as to cover the cast when it is tapped out. When the iron is poor in carbon, that portion of the cast which has cooled under the slag is invariably more bladed in texture than when not so covered, but if the iron is very rich in carbon (containing say 5 per cent. carbon), but little difference is observable. It is, therefore, advisable to let the iron run out of the furnace as quickly as possible, as, if not so done, it frequently happens that the iron does not have the desired bladed texture well developed in it; when the percentage of manganese in the cast iron is large, and the iron is tapped very hot, a strong oxidation, with evolution of flames, is seen on the surface of the cast, and presents a very curious appearance.

In these works, in order to get good results, care is taken to work the furnaces slowly, so as to keep the manganiferous ore exposed as long as possible to a powerful reducing action, in order to get as much of the manganese reduced along with the iron as possible, and for this purpose, a strong pressure, very hot blast, and very basic charge is required; the zone of combustion must not (as occasionally happens in Westphalia) be allowed to rise too high above the tuyeres, and should this take place, the remedies in general use are to diminish the pressure of the blast and use the ore in a finer state of division, and wet it with water; in Westphalia, this is generally attributed to the charcoal or coke being of a worse and more open porous texture than usual.

Coke is becoming more and more used, and is now alone employed at the Charlottenhuette, which alone produces nearly one-half of the spiegeleisen made in the district. All accounts agree that it is much superior to either charcoal or the mixture of charcoal and coke, provided only it be of good quality and free from sulphur, and it is stated, when coke is employed, that several percentages more of manganese can be got into the spiegeleisen than when the same charge is smelted with charcoal, and, for this reason, it is particularly suited for smelting ores rich in manganese. It is also stated that in this district the attempts to increase the amount of manganese in the spiegeleisen by manganese ores added

to the charge have not succeeded, and that the manganese in such additions has for the most part gone into the slag.

Spiegeleisen, showing an apparently identical fracture to the eye, may vary immensely in its percentage of manganese, and in practice each cast or tapping should be assayed for itself. This, however, is not done in the Siegen district, where, although it is the general custom to regard the spiegel as containing an average of 10 per cent., it will be found in actuality to vary from 7 to 11 per cent. when analysed.

The following analyses show the chemical composition of spiegeleisen from this district when made with coke:—

	Hamm.	Hochdahl.
Carbon	4·129	5·04
Silicon	0·458	0·41
Sulphur	0·015	0·08
Copper	0·291	0·16
Manganese	8·706	7·57
Iron	85·929	86·74
	99·528	100·00

The cost of making spiegeleisen at the Lohe furnace, based on one week's work, and using a mixture of coke and charcoal, was stated, in 1869, to be approximatively as follows:—

	£	s.	d.
190 tons roasted spathic iron ore	149	0	0
55½ " limestone	8	7	0
6,150 cubic feet charcoal	67	17	0
48½ tons coke	34	19	0
Crushing 55½ tons limestone	1	8	0
Breaking up and stacking 85 tons spiegeleisen	0	16	0
Carriage of slag	2	15	0
Wages of furnacemen	11	0	0
Management	5	12	0
Total cost of 85 tons spiegeleisen	£281	14	0

(Or about £3 6s. 4d. per ton.)

Using charcoal alone, this cost price would be increased to about £3 12s. 8d. per ton, but, with coke alone, it would be diminished to about £3 per ton. As the prices of ore, fuel, and labour have much

increased since 1869, the cost of spiegeleisen at present will, however, be considerably higher than the above estimate.

IRONFOUNDING.—A paper on the choice of cast iron and mixtures for cast iron foundry purposes, by A. Ledebur, is published in Nos. 45, 46, and 48, of the Berg u. Huetten. Zeitung, for 1871; the contents of which, owing to its length, could not be properly abstracted in the space at disposal in this report, but are well worthy of study, as an attempt to reduce to definite rules the results of practice in this department of ironfounding, which, it is to be feared, are too often left all but entirely to chance, and but little understood in reality.

Mr. M. Wilson, of Coldspring, New York, U.S., has patented what he terms "improvements in furnaces for melting iron," which relate to a furnace so constructed, that large heavy masses of cast iron can be placed in it and melted down. The top of the furnace is provided with a sort of moveable hood, which, when the furnace is to be charged, is removed by the aid of a crane; upon the bottom of the furnace two rests or bearing pieces are arranged, upon which the weight of the iron is supported, and the bottom itself rests on hinged plates, which can be opened so as to obtain access to it.

SEPARATION OF PHOSPHORUS IN PUDDLING.—According to the Berggeist, Nos. 92 and 94, for 1871, some trials made at Thale in the Harz, in puddling Ilseder pig iron along with $1\frac{1}{5}$ per cent. of its weight of fluorspar, have resulted in producing a fibrous bar iron when rolled, which is not at all coldshort, a result altogether unexpected, since this pig iron is known as one of the cheapest brands of German iron, for notwithstanding that it contains from 3 to 5 per cent. manganese and only about 0·1 per cent. of sulphur and silicon, it has, on account of its large percentage of phosphorus, been much more difficult to sell than the common irons, like that made from minette, which only contains 0·2 per cent. of manganese, but is, however, not so rich in phosphorus as the Ilseder pig.

ROLLING.—A paper, by Urbin, on the calibration of rolls, which originally appeared in the Bulletin des Ingenieurs, is re-published in German, with illustrations, in the Berg u. Huetten. Zeitung, Nos. 41, 43, and 45.

A wire brush for removing the scale from large round bars as they are passing through the rolls is employed at the Griswold rolling mill, at Troy, United States; the brush is fastened to the

rest bar on the discharging side of the rolls, and the bar passing through its wires is found to be effectually cleaned from scale by the time it has made its usual number of runs through the grooves.

Schuchardt, in the Zeitsch. d. Deutsche. Ing., 1871, p. 416, gives a notice of a method of repairing broken rolls, which consists in heating the end of the broken roll to a red heat, with a fire of charcoal or coke made upon it; if coke is used, a blast of air is required to assist combustion, after which a clay mould is fixed on to the end, having an aperture in its side of about one inch diameter, and about 1¼ inch above the fractured end of the roll. Molten iron is now poured continuously into this mould and allowed to flow as a stream out of the aperture (from which it may be directed so as to run into other moulds for castings placed close to it) until the surface of fracture begins itself to melt, upon which the hole is stopped and the moulds filled up entirely.

Siemens-Martin Steel Process.—A sketch of the advantages and disadvantages of this process, as compared with the Bessemer system of steel making, is given in the Zeitsch. d. Berg u. Huett. Vereins f. Karnthen, 1871, No. 9, in which it is admitted that the improvements made in this process have now reduced the great expense of repairs and cost of fire-resisting material to as low as in the Bessemer process, but maintains that neither the hopes, at first entertained, that a less good quality of raw material (such as iron containing more phosphorus) than is necessary in the Bessemer process, could be utilised in these furnaces, have been corroborated by practical experience, nor has that precise uniformity in the quality or hardness of the steel, so desirable, been secured; although with extremely good raw materials, a product, nearly equal to crucible steel, can be obtained at much less expense for fuel; still this process, which appears to be best suited for making hard steel, is not allowed to have, as yet, acquired the certainty in results obtained by the Bessemer system.

Bessemer Process.—In the Swedish, Austrian, and most of the German Bessemer steel works, spiegeleisen is not employed as in England, France, and Belgium, but the "blow" is stopped at a point when the molten metal contains the amount of carbon necessary to secure steel of the desired hardness. At the Kœnigin Marien Huette, spiegeleisen is only used in case the "blow" has been driven too far, and at Hoerde, it is put cold into the pouring

ladle. At the Bessemer works, at Zeltweg, in Austria, hot blast is now employed for the converters, but we have not, as yet, been able to get information as to the results. On the Continent everywhere, cupolas are being substituted for air furnaces for melting the Bessemer pig, for the special reason that the former do not eliminate the silicon from the iron, it being desirable to keep this element in the converter, since it acts like carbon in augmenting the heat of the metal. In Germany, the home-made Bessemer pig, to which, in most works, more or less Cumberland hematite pig is added, generally contains two or more per cent. of manganese, and this is also the case in Sweden. The spectroscope has come into very general use on the Continent for determining the point at which the blow is finished, which is usually stopped at the precise moment when the line Mn α disappears from the spectrum.

At the Westanfors Bessemer Works, in Sweden, the pig iron is tapped directly from the blast furnace into the converter, or rather, is first allowed to flow into a large ladle, which is weighed, and then poured into the 2½-ton converters, which are moved by a rack and pinion by four men. The blast furnace is fifty feet high, with two tuyeres, and produces about 3,000 tons Bessemer pig per annum, which is reduced from native oxides of iron containing some manganese, and smelted by charcoal. Grey iron is not sought for as in England, the pig is white, or greyish white at most, and a sample bar taken of each tapping. No spiegeleisen is employed, and Mr. Brusewitz, the manager, stated that they find no difficulty in producing steel of any degree of hardness considered desirable, it being only requisite to tip up the converter when the "blow" has proceeded so far as to produce hard steel, and take out a sample in a small ladle, from which, in four minutes, the amount of carbon contained in it is found, after which it is only necessary to continue the blow a certain number of seconds more, according to the degree of hardness required. To be quite certain, however, a second trial is often taken before the steel is poured, yet the steel always remains quite hot enough notwithstanding these interruptions.

On "The Attainment of Uniformity in Bessemer Steel" is the title of a paper recently read before the American Institute of Mining Engineers, by Dr. T. M. Drown, but as a full account of this communication has already appeared in the Chemical News of January 13th, this year, we must refer to that periodical for its contents.

In the Annales du Génie Civil, for October, 1871, will also be found an article, by A. Greiner, on the use of Bessemer steel at Seraing, which considers the chemical composition and physical properties of the different kinds of steel, and describes the classification, tests of strength, and nomenclature of the steel made at Seraing, concluding with details of its application to the manufacture of springs, tyres, &c.

Analyses of Bessemer Steel.—From a very excellent report to the Iron Office of Sweden, on the German, Austrian, and English manufacture of Bessemer steel, based on data collected in 1870, during a journey in these countries, by Mr. E. Brusewitz, which is published in Jern Kontoret's Annaler for 1871, pp. 199–249, we extract the following analyses:—

	Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
Steel made, direct from the blast furnace without addition of spiegeleisen, at Westanfors, in Sweden	0·085	0·008	trace	0·025	trace
Ditto	0·300	0·044	0·179	0·033	do.
Ditto	0·700	0·032	0·256	——	do.
Ditto	0·950	0·047	0·463	0·032	do.
Ditto	1·050	0·067	0·355	——	do.
,, Barrow-in-Furness (for coarse wire) ...	0·200	0·179	0·214	0·026	0·030
,, Germany, for railheads	0·138	0·306	0·386	0·134	0·040
,, ,, for rails (from iron poor in manganese)	0·150	0·091	0·264	0·132	0·025
,, Germany, for rails, from mixture of Workington hematite pig with German manganiferous pig	0·046	0·634	0·638	0·093	0·045
,, From Neuberg, for boiler plate, direct from blast furnace	0·250	0·016	0·136	——	0·010
,, From Neuberg (iron first re-smelted in cupola)	0·300	0·056	0·273	0·041	0·040

Analysis of Bessemer Converter Slag.—The analysis of the converter slag produced along with the steel, containing 1·05 per cent. of carbon, the composition of which is given amongst the above analyses, has been forwarded by Mr. Brusewitz to the Foreign Secretary:—

This slag was of a light brown colour, and contained numerous crystals, the angles of which were approximatively 45° and 135°. It contained:—

Silica	46·700
Alumina	4·246
Protoxide of iron	15·632
,, manganese	32·367
Lime	0·481
Magnesia	0·172
	99·598

Analysis of Swedish Charcoal Bessemer Pig.—This pig iron, made expressly for conversion into steel by the Bessemer process, when tapped direct from the blast furnace at Westanfors, without any addition of spiegeleisen, has also been analysed by Mr. Brusewitz :—

Carbon combined	3·342
„ graphitic	1·710
Silicon	0·748
Phosphorus	0·031
Sulphur	0·005
Manganese	3·119
Iron	91·045
	100·000

Tests for Bessemer Steel Rails.—At the Bessemer Steel Works, at Gratz, belonging to the Austrian Southern Railway Company, the steel rails are submitted to two tests; 1st, for elasticity, which consists in placing a weight of $17\frac{1}{2}$ tons on the middle of the rail, whilst resting upon two supports, placed respectively at a distance of three feet from one another; and 2nd, for fracture, in which the rail, when supported as above, must stand, without breaking (any amount of bending is allowed), a blow of one ton, let fall from a height of fifteen feet.

Chromium Steel.—Cast steel, in which the carbon is in part, or wholly replaced by the metal chromium, is attracting considerable attention in the United States, where a company, called the Chrome Steel Company, now produce this steel in large quantities by processes patented by a Mr. Bauer. It is claimed for this steel that it is capable of sustaining a greater degree of heat than ordinary steel, and, consequently, is not so liable to become oxidised or "burnt" in working; it is said to work quite as easily, and to roll much more smoothly than ordinary steel. It is stated to be made in crucibles, but otherwise we have no details of the mode of manufacture. According to a report of Captain Eads, chief engineer to the Illinois and St. Louis Bridge, this steel has been employed in those parts of this bridge where very great strength was required with perfect success, notwithstanding that anchor bolts and staves made from the usual cast steel had, as a rule, failed to

sustain the tests fixed by the terms of the contract, the particulars of which are given in the second quarterly report for 1871.

SILICON STEEL.—This name has been given to a new variety of steel, containing a greatly increased percentage of silicon in proportion to that of the carbon, as compared with ordinary steel. It is patented by Mr. Nes, of York, Pennsylvania, United States, who, in order to introduce the silicon into the steel, makes use of silicious magnetic oxide of iron from Heidelberg, York County, Pennsylvania. Although this steel is stated to possess characters different from any known steel, no details have as yet been received, either as to its qualities, or mode of manufacture, and as yet it does not appear to have been practically tested.

STEEL TYRES.—The report of the Steel Tyre Committee, appointed by the Association of Master Mechanics in the United States, to enquire into the durability, &c., of the steel tyres in use on the various American railroads, has been published, and contains valuable information obtained from twenty-six railway companies, in answer to a circular sent to them containing a series of questions.

From this report we extract the following figures, which show the relative durability of the tyres obtained from the the following makers, as far as could be ascertained from the reported performance of 653 sets of tyres:—

Miles run for each $\frac{1}{16}$ of an inch in wear.

	Of any Single Set.		Average on any Railroad.		General
	Highest.	Lowest.	Highest.	Lowest.	Average.
Krupps	123,347	2,671	49,704	9,199	15,150
Vickers	79,661	1,081	46,122	8,180	17,983
Firths	78,225	2,038	31,674	9,346	15,463
Butchers	38,237	6,855	38,237	6,855	14,685
French	30,170	4,230	—	—	11,029
Bessemer	15,718	10,137	—	—	12,129
Taylor	55,522	10,137	—	—	16,802
Lowmoor	15,943	1,579	—	—	7,220
Washburn	15,635	8,452	—	—	12,557

AMOUNT OF SILICON IN IRON AND STEEL.—Boussingault, in the Ann. Chim. Phys., 4th Series, vol. XXII, p. 471, has given the following figures as the results of this determination of silicon, in

various samples of cast and wrought iron and steel, by his new process:—

Grey cast iron from Ria	0·01400
White do. do	0·00340
Cast steel	0·00070
Cast blister steel	0·00440
Cast steel, Krupps...	0·00440
„ for carriage springs	0·00094
„ for watch springs	0·00044
Tungsten steel	0·00093
Wootz steel	0·00062
Chinese	0·00070
Soft steel	0·00093
Bar iron	0·00190
Puddled iron from Unieux	0·00093
Swedish iron	0·00164
Iron wire	0·00230

Estimation of Silicon in Iron and Steel.—Boussingault, in the Ann. Chim. Phys., Ser. 4, vol. XXII., pp. 457-472, has described in detail a new dry process for determining the amount of silicon contained in iron or steel, which he considers is free from those sources of error which, in the old processes, tend to vitiate the results. The process is based on: 1st, The action of air at a red heat to oxidize the iron, carbon, and silicon; and 2nd, The action of dry hydrochloric acid upon such oxidized product, to convert and volatilise the iron as a chloride, leaving only the silica behind. It is requisite to effect the operation in two stages, since otherwise the silicon might also be in part or wholly carried off with the iron in the state of chloride before being converted into silica.

The process is recommended to be executed as follows:—About one gramme of the metal, in a tolerably fine state of division, is placed in a platinum boat, and exposed in a muffle to a good red heat, such as used in cupelling silver; in two or three hours the iron is completely oxidised and converted into magnetic oxide; the boat, with its contents, is now placed in a porcelain tube heated to redness, and exposed to a slow continuous stream of dry hydrochloric acid gas, by which the whole of the iron is now volatilised, leaving the silica behind in the platinum boat to be withdrawn and weighed. It is found to be perfectly white, in an

extremely fine state of division, and usually retains the form of the oxide of iron in the boat when put into the tube. It is, of course, requisite to moderate the rapidity of the current of hydrochloric acid gas during the operation, to avoid its carrying off any of this finely divided silica in mechanical suspension. The purity of the silica is tested by hydrofluoric acid, with a little sulphuric acid; on warming, the whole should volatilise; usually, the silica entirely disappears, but occasionally cast iron leaves a small residue, probable from admixture of slag in the metal. Phosphorus does not remain behind, but is entirely volatilised, as was demonstrated by special experiments.

Determination of the Iron in Slags.—Lundstrom, of the Filipstad School of Mines, in Sweden, recommends, especially for such slags as are not easily or completely decomposed by acids, that the finely pulverised slag should be mixed in a platinum crucible, with from three to four times its weight of fluoride of ammonium; the crucible is then heated on a water-bath, and sulphuric acid is added by degrees, until all effervescence ceases, after which, it is heated on a sand-bath, or otherwise, until vapours of sulphuric acid begin to be given off. When cold, the contents of the crucible are treated with water, which will dissolve all except some sulphate of lime, which is filtered off; the filtrate is then heated with metallic zinc, until the whole of the iron is brought to the state of protoxide, after which it is titrated by permanganate of potash, as usual.

Estimation of Manganese in Spiegeleisen.—In order to arrive at an approximative estimation of the amount of manganese in each tapping of this variety of iron as quickly as possible, in order to control the working of the blast furnaces, it is customary at Schisshyttan, in Sweden, merely to determine the iron by dissolving it, and titrating with permanganate of potash; by adding 5 per cent., which is the average amount of carbon and silicon present in the spiegeleisen, to the percentage amount of iron found, and subtracting this sum from 100, the amount of manganese is found with sufficient accuracy for the object in view.

Determination of Phosphorus and Sulphur in Cast Iron.—Meinecke recommends a modification of Gintl's process (described in the third quarterly report for last year) using chloride of copper instead of chloride of iron. According to him, the iron should be dissolved in a solution of chloride of copper; the insoluble matter,

containing all the sulphur and phosphorus (but not all the silica), after being oxidised by nitric acid, with addition of chlorate of potash, is evaporated to dryness with the addition of hydrochloric acid; from the re-solution of this, the sulphur is precipitated as sulphate of barium, and the filtrate then thrown down by ammonia, gives a precipitate, from which, when dissolved in nitric acid, the phosphorus may readily be determined by molybdate of ammonia, as usual.

With reference to the prize offered by the Association for the Advancement of Prussian Industry, for an improved process for determining phosphorus in iron, the conditions of which were given in the third quarterly report for last year, the Foreign Secretary has been informed by Professor Wedding, of Berlin, that it has not as yet been awarded to any one, and, consequently, is still open to competition.

February 1, 1872.
11, York Place, Portman Square, London, W.

VISIT OF THE INSTITUTE TO SOUTH STAFFORDSHIRE, 1871.

In the last issue of the Journal, we had not sufficient space to notice the arrangements made by the South Staffordshire Local Committee for enabling the members to visit the principal works in the district.

The business meetings were held at the Mechanics' Institute, Dudley, the whole of the rooms required, having been, in the most liberal manner, placed at the disposal of the Institute gratuitously. The Museum, in connection with the Mechanics' Institute, and under the joint management of the Dudley Institute and the Geological Society, was also available for the members. This collection is specially and almost exclusively devoted to specimens illustrating the geological features of the immediate neighbourhood. It is particularly rich in fossils from the Silurian rocks near Dudley, that have for many years been extensively worked for the purpose of supplying limestone to the blast furnaces on the surrounding coalfield.

After the business had been completed on Tuesday morning, August 29th, the members proceeded by special train to Tipton, where luncheon had been provided by the ironmasters of the Tipton district. Mr. Walter Williams occupied the chair. During the afternoon, the works in the neighbourhood were visited, including Gospel Oak, Wednesbury Oak, Bloomfield, and Summerhill. The special train also proceeded to Wolverhampton, where the Chillington, Shrubbery, Swan Gardens, Horseley, and other works were open for inspection.

On Wednesday afternoon, the members went by special train to Round Oak, and inspected the works of the Earl of Dudley. They were afterwards entertained at luncheon by the noble proprietor, who occupied the chair, and gave a cordial reception to the Institute. In the evening, the Earl of Dudley ordered a brilliant illumination of the extensive artificial caverns beneath the Castle Hill, Dudley, in honour of the visit of the Institute.

In the Public Hall, Dudley, Mr. P. Würzburger exhibited a map of the hematite district of Furness, which we reproduce in this issue of the Journal, together with a short description of the same. Mr. E. B. Marten, Stourbridge, exhibited a geological model illustrating the position of the rocks in the vicinity of Dudley; also, a number of beautifully-executed models, explanatory of the principal boiler explosions that have occurred during the last few years. Mr. Winby showed a model of his method of laying down permanent way. Mr. Henderson exhibited samples of iron made after treatment by his fluorspar process. Mr. Edward Williams exhibited a portion of the first rail made of Bessemer steel. Mr. Thomas Whitwell showed a model illustrating the manner in which the materials arrange themselves as they are charged in the blast furnace, by means of the bell and hopper plan. Messrs. Thompson and Co., of Normanton, submitted a specimen of Bessemer rails manufactured by them; Mr. Griffiths, an improved pile; Messrs. Jno. Brotherton & Co., patent wrought iron machine-made fittings; and Mr. Ash, an improved miners' dial.

On Thursday, August 31st, the members visited the principal industrial establishments in Birmingham, which were kindly thrown open upon that day by the proprietors. In the evening, the members of the Institute were entertained at dinner in the Exchange Assembly Rooms, by the South Staffordshire Ironmasters' Association. The Earl of Dudley occupied the chair, and was supported by Lord Lyttelton, and the leading members of the iron trade. Mr. Abraham Hewitt represented the American iron trade, and Mr. Krans that of Belgium. A melancholy circumstance occurred in connection with the banquet,—Mr. William Mathews, one of the oldest and most experienced of the Staffordshire ironmasters being seized with a paralytic stroke, which resulted in his death a few days afterwards. Mr. Neilson, in the name of the ironmasters of Scotland, invited the Institute to hold the next provincial meeting at Glasgow.

On Friday, September 1st, the members visited the works of the Lilleshall and Coalbrookdale Iron Companies. They proceeded by special train and inspected the hot and cold blast furnaces of the former firm; also, their malleable ironworks and engineering establishments. The foundries and works at Coalbrookdale were afterwards visited. In the Literary and Philosophical Institute a

collection of objects of interest to the iron trade was exhibited, including drawings of arrangements that had been in operation at Coalbrookdale in the earliest period of the iron manufacture in that district; models of engines of a bygone type; specimens of iron and ironstone; and also illustrations of the beautiful castings now made by the company. The members were afterwards entertained at luncheon by the Shropshire ironmasters, Mr. W. O. Foster presiding. The members returned by special train to Wolverhampton, and the proceedings of the meeting terminated.

All the arrangements made by the Local Committee were most complete, and the Institute is much indebted to the members of that committee, and especially to the Chairman, Mr. J. P. Hunt, and the Secretary, Captain Mitford, for the valuable assistance they rendered in making the meeting, held in South Staffordshire, one of the most successful gatherings that has yet been held under the auspices of the Institute. The best thanks of the Institute are also due to the proprietors of ironworks in South Staffordshire, (the whole of the works with one exception were available for inspection,) and to the owners of works in Birmingham; to the Earl of Dudley, and the gentlemen connected with the South Staffordshire and Shropshire iron trades for their hospitable entertainment of the members; to Mr. Harding, secretary of the Birmingham Exchange, for his assistance in connection with the arrangements in Birmingham; to the Council of the Birmingham Exchange, of the Dudley Mechanics' Institution, of the Dudley Geological Society, and of the Dudley Institute of Mining Engineers, for facilities they afforded the members during their visit, and to many other gentlemen who in various ways contributed to the success of the meeting.

NOTES ON
THE BRITISH IRON AND STEEL TRADES.

Since the last issue of the Journal, the death of Sir Roderick Murchison has occurred. The deceased gentleman was for many years Director-General of the Geological Survey of Great Britain, and in this capacity he pushed forward vigorously the completion of the geological survey of the country. The high scientific attainments of Sir Roderick are too well known to render a recapitulation of them at all necessary. Under his able direction, the progress of the Geological Survey was much more rapid than it had previously been, though even up to the present time the money granted annually for this important industrial work is exceedingly inadequate, considering the magnitude of the interests involved. Until the survey is completed it will be impossible to form an adequate estimate of the extent of our mineral resources, and it is, consequently, very desirable that the work should be finished with as little delay as possible. Sir Roderick Murchison rendered good service to the iron trade during the time he filled the office of Director-General. He succeeded in associating with him many men of eminence in the geological world, whose labours cannot fail to be of great value to the nation. His varied scientific attainments were recognised not only at home, but by all civilised nations, and few men have descended to the grave loaded with more honours. His name will be handed down to posterity as one of the foremost geologists of the nineteenth century.

It is reported that extensive deposits of iron ore (impure spathic carbonate) are being opened up in Teesdale. Since the first announcement of the discovery of this ironstone further explorations have been made, the result of which is that large quantities of ore have now been proved to exist in the locality above mentioned; but from the want of adequate railway accommodation, it will be some time before the material can be worked on an extensive scale. Further north, other deposits of hematite

and carbonate of iron are about to be worked, provided a railway is constructed that will place the mines in direct communication with the ironworks of Cleveland.

A College of Physical Science has been successfully started in Newcastle-on-Tyne, in connection with the University of Durham. The movement has been mainly carried out by the leading manufacturers and mine owners in the North Country. The establishment of this institution can hardly fail to be a great benefit to the iron and coal trades of the district round Newcastle. The professors appointed are all men of eminence in their respective departments. We understand that the number of students is fully equal to the expectations of the promoters of the College.

At a meeting of the South Wales Institute of Engineers, held at the end of October, a paper was read on wire tramways. It was stated that such tramways were coming into extensive use, and that a line could be constructed to carry 1,000 tons of material daily for £2,880 per mile. At that time it was reported that from 90 to 100 miles of wire tramways were constructed or contracted for.

At a meeting of the South Staffordshire Institute of Mining Engineers, held at Dudley in November, it was reported that the explorations of Mr. J. S. Dawes in search of thick coal, south of the known limits of the coalfield, had at length been successful. Mr. Dawes has been prosecuting his search for about seven years. The pits he originally sunk only passed through a seam of coal four feet in thickness, and then the Silurian Rocks were reached. A drift was, however, driven to the north-west about 1,000 yards, when a seam of coal 14 feet in thickness was found. This discovery has rendered it probable that a large area of productive coal and ironstone measures will be opened up in the neighbourhood of Hales Owen.

Mr. Thomas, and Mr. Howson, Britannia Iron Company, Middlesbrough, have patented a mechanical puddling apparatus. The revolving portion of the machine moves backwards and forwards upon a bogie when iron has to be charged or material withdrawn.

At a meeting of the Chemical Society, held in November last, Professor Odling, F.R.S., vice-president, in the chair, a paper on the above subject, by Mr. W. H. Johnson, was read, in which the author expressed his opinion that the burning of iron and steel is not due to the action of uncombined oxygen. He stated that Mr. W. Mattieu Williams thinks this to be the

case, but the oxygen does not exist in a free state in the hottest part of the furnace, as it is there united with carbon, forming carbonic acid and carbonic oxide. After referring to Mr. I. Lowthian Bell's experiments on the oxidising effect of carbonic acid, and the reducing action of carbonic oxide on iron at different temperatures, the author drew attention to the fact, that immediately the oxidising effect of the carbonic acid present becomes greater than the opposite action of the carbonic oxide, the iron begins to burn. The relative proportion of the two gases at which the point of equilibrium occurs varies greatly with the temperature; the higher this is, the smaller is the proportion of carbonic acid in the mixed gases necessary to produce the injurious effect; it takes place, moreover, with greater readiness when a comparatively pure iron is employed than with one containing sulphur or silicon. As red-hot iron is permeable to carbonic acid and carbonic oxide, their action is not confined merely to the surface, but penetrates into its substance. This induced the author to believe that the well-known increase of bulk which takes place when iron is repeatedly heated, is due to the formation of an oxide in the body of the metal, thereby increasing both its volume and its weight. Dr. Odling thought that the relation between the burning of iron and steel, the experiments of Mr. I. Lowthian Bell on the varying oxidising power of carbonic acid at different temperatures, and the corresponding reducing action of carbonic oxide, were of great interest, showing that there was a point at which these actions, going on at the same time, so to speak, neutralised one another.—Mr. Riley was sorry he only heard the latter part of the paper, and said that the mechanical treatment of iron should be considered quite as much as the chemical composition of the iron. Thus iron that was quite brittle, such as puddlers' old rabbles, when piled, heated, and rolled two or three times, became fibrous to a certain extent, and much improved in quality. The best fibrous wrought-iron, after being melted, became very red-short. Much misconception existed as to the injurious action of the so-called impurities in iron. He found that excellent tool steel that worked well under the hammer, and stood the severest tests (burning off the skin of cast-steel wheels) contained an amount of silicon that would be very prejudicial in white cast iron, and make it difficult to puddle. In reply to Dr. Odling's queries as to sulphur and phosphorus, he considered sulphur mostly injurious, although

it made No. 1 pig stronger (the most highly graphitic iron) by reducing it to Nos. 3 or 4. He considered that in pig iron, a certain amount of phosphorus was advantageous, as without it the iron, when puddled, worked red-short; thus the best Swedish pig made a red-short iron, and its quality would be improved by mixing a lower quality containing phosphorus with it, such as Cleveland or Derbyshire pig. Low Moor and Bowling pig contains uniformly about 0·64 per cent. of phosphorus, the amount being the same generally when the best clay ironstones are used in South Wales, either with hot or cold blast; there was no doubt that such pig made the best wrought iron, and commanded a higher price than Swedish charcoal pig. Phosphorus in steel is certainly injurious, and anything much over 0·10 per cent. he considered detrimental. The sample referred to contained 2·07 per cent. of silicon. In puddling iron, he considered it was essential to have some silicon in the pig; good white forge pig usually contains from $\frac{3}{4}$ to 1 per cent., whereas inferior white pig frequently contains only $\frac{2}{10}$ to $\frac{3}{10}$ per cent. Tungsten is being used by Mr. Mushet in his so-called "special" steel; it contains more than 10 per cent., and is an excellent steel for certain kinds of cutting tools; it requires no hardening.—Dr. Muller asked whether the so-called Mushet's "titanium steel" contained titanium, as he had been unable to detect any in a sample he had examined.—Mr. Riley said that he had never found titanium in any white iron, and believed that it occurred only in grey iron.

It is reported that a deposit of hematite has been discovered on the shores of Lough Erne, County Fermanagh, Ireland.

At the last December meeting of the Manchester Literary and Philosophical Society, Mr. John Hopkinson, B.A., D.Sc., detailed some experiments on the effect of repeated blows on wire, the results of which are—1st, That if any physical cause increase the tenacity of wire, but increase the product of its elasticity and linear density in a more than duplicate ratio, it will render it more liable to break under a blow. 2nd. That the breaking of wire under a blow depends intimately on the length of the wire, its support, and the method of applying the blow. 3rd. That in cases such as surges on chains, &c., the effect more depends on the velocity than on the momentum or *vis viva* of the surge. 4th. That it is very rash to generalise from observations on the breaking of structures by a blow in one case to others even nearly allied, without carefully considering all the details.

The Board of Trade Returns for 1871 give the following as our exports of iron and steel for the 12 months ending 31st Dec., 1871 :—

IRON.

	Articles, and to what Countries Exported.	1870. Tons.	1871. Tons.
Pig	To Germany	126,178	203,359
	,, Holland	156,879	244,557
	,, France	92,441	72,176
	,, United States	113,980	188,113
	,, Other Countries	263,861	352,799
	Total	753,339	1,061,004
Bar, Angle, Bolt, and Rod	To Germany	11,511	15,093
	,, Holland	10,197	8,363
	,, France	4,137	785
	,, Italy	33,127	31,882
	,, Turkey	11,645	11,318
	,, United States	50,538	64,301
	,, British North America	38,939	45,457
	,, ,, India	29,855	27,377
	,, Australia	12,507	12,384
	,, Other Countries	118,999	132,166
	Total	321,455	349,126
Railroad of all Sorts	To Russia	207,676	79,119
	,, Sweden	2,933	9,170
	,, Germany	52,660	50,288
	,, Holland	15,466	14,811
	,, France	372	2,654
	,, Spain and Canaries	13,195	13,318
	,, Austrian Territories	38,434	24,189
	,, Egypt	2,333	14,784
	,, United States	421,824	511,059
	,, Spanish West Indian Islands	3,709	3,152
	,, Brazil	5,890	20,528
	,, Peru	13,843	28,949
	,, Chili	17,273	11,262
	,, British North America	36,291	61,733
	,, ,, India	153,137	34,707
	,, Australia	8,691	14,110
	,, Other Countries	65,665	85,184
	Total	1,059,392	979,017
Wire (except Telegraph) galvanized or not		23,447	26,057
Hoops, Sheets, and Boiler & Armour Plates	To Russia	11,253	17,529
	,, Germany	9,837	14,446
	,, Holland	8,290	8,510
	,, France	3,109	1,907
	,, Spain and Canaries	4,757	5,122
	,, United States	39,228	41,498
	,, British North America	11,980	16,278
	,, ,, India	16,342	16,074
	,, Australia	13,515	13,899
	,, Other Countries	63,173	66,056
	Total	181,484	201,319

Cast or Wrought and all other Manufactures (except Ordnance unenumerated) ..	To Russia	21,134	14,635
	„ Germany	17,035	23,204
	„ Holland	5,677	12,447
	„ France	4,433	4,422
	„ Spain and Canaries	5,916	4,146
	„ United States	9,661	10,637
	„ British North America	12,376	16,207
	„ „ Possessions in South Africa	2,321	2,331
	„ „ India	35,082	29,478
	„ Australia	19,388	18,708
	„ Other Countries	100,698	108,112
	Total	233,721	244,327
		Cwts.	Cwts.
Tin Plates ...	To France	25,158	42,426
	„ United States	1,507,455	1,738,588
	„ British North America	59,759	83,128
	„ Australia	63,006	106,197
	„ Other Countries	341,641	424,753
	Total	1,997,019	2,395,092
		Tons.	Tons.
Iron, Old, for re-manufacture		106,749	138,831

STEEL, Unwrought.

To France	2,221	1,662
„ United States	17,787	21,157
„ Other Countries	14,954	16,351
Total	34,962	39,170

Manufactures of Steel or Steel and Iron combined	11,175	12,975
Total of Iron and Steel	2,825,575	3,171,581

Mr. A. Spencer, whose revolving puddling machine is described elsewhere, states (under date January 27) that his apparatus is at work at West Hartlepool, and gives every sign of permanent success. On the previous day, a heat was puddled and balled, from molten iron, in 22½ minutes, all of which was hammered and rolled off into narrow bars. About 10 cwt. is puddled at each charge.

The Machine Tunneling Company have lately completed a boring undertaken for the Stanghow Ironstone Company, near Middlesbrough, the machine used being the patented invention of Captain Beaumont, R.E., and M.P. for South Durham. The working of the machinery during the period of its operations at Stanghow has given great satisfaction. Boring was commenced on October 7, and continued during the short days, in day time only, up to December 4, when the boring was completed. During the first 15 days a depth of 107 feet was reached; 86 feet of this was hard

oolitic sandstone, and a hard rock containing crystals of quartz. In other 12 days' boring a further depth of 220 feet had been penetrated, and the shale overlying the top seam of ironstone was reached at a distance of 368 feet from the surface. At this period the weather became unfavourable, the pumps were frozen, and considerable delay consequently ensued. Operations being again continued, the remaining depth of 321 feet, being 689 feet from the surface, was attained on December 16, the main seam of ironstone being cut through a little above that depth. One good feature of this mode of boring is that a sample of the mineral, in the shape of a core one inch diameter, is obtained the whole of the depth. Thus, in 60 short days, including all stoppages and the delay from frost, the Stanghow main seam of ironstone was reached, and cores were obtained showing precisely its quality. The boring apparatus was driven by a small portable steam engine, connected with it by a belt. The boring-tube being set with diamonds at the cutting part makes an annular perforation through the strata, the outer circle being two inches, and the inner one one inch in diameter, the *debris* being carried away from the boring tool by a circulation of water. The tube requires to be withdrawn only to obtain the core, going as far as 20 feet without being entirely lifted.

During the last three months several gentlemen intimately associated with the iron trade have been removed by death. Mr. Walter Pease (Pease, Hutchinson, & Co., Darlington), Mr. Crawshay Bailey (Nantyglo, Monmouthshire), Mr. James Bagnall (Golds Hill, South Staffordshire), and Mr. Joseph Pease (Darlington).

In the last issue of the Transactions of the Institution of Mechanical Engineers will be found a description of Miller's cast iron steam boiler.

The Mineral Statistics for the year 1870 have recently been published. We extract the following information relative to the figures connected with the iron and coal trades.

Mr. Hunt has ascertained that the manufacture of pig iron shows an increase as follows :—

In 1868,	pig iron made was		4,970,206	tons.		
„ 1869,	„	„	5,445,757	„	increase,	475,551 tons.
„ 1870,	„	„	5,963,515	„	„	517,758 „

The production of coal has increased in a corresponding degree, for

In 1868, we produced	103,141,157 tons,			
„ 1869, „	107,427,557	„	increase, 3,286,400	tons.
„ 1870, „	110,431,192	„	„ 3,003,635	„

The production of iron ore is given as follows:—

Counties	Tons.	cwts.
Cornwall	11,214	4
Devonshire	10,193	17
Somersetshire	19,739	7
Gloucestershire	183,503	9
Wiltshire	101,423	0
Oxfordshire	38,803	17
Northamptonshire	761,248	0
Lincolnshire	248,329	17
Shropshire	337,627	0
Warwickshire	17,500	0
Staffordshire, North	910,134	0
Staffordshire, South	450,000	0
Derbyshire	384,865	0
Lancashire and Cumberland	2,093,241	4
Yorkshire, West Riding	307,717	0
Yorkshire, North Riding, Northumberland, Durham	4,298,220	1
North Wales	59,240	0
South Wales and Monmouthshire	560,055	2
Scotland	3,500,000	0
Ireland	77,600	0
Total iron production in the United Kingdom...	14,370,654	18

The total quantity, as above shown, was 14,370,654 tons, and foreign ores imported, 208,310 tons, therefore the total of iron ore smelted in Great Britain was 14,578,964 tons. The number of furnaces in blast was 664, and the quantity of pig iron produced—

In England was	3,735,627	tons.
„ Wales „	1,021,888	„
„ Scotland „	1,206,000	„
Total ...	5,963,515	„

The Summary of this produce is thus given :—

COUNTIES.	No. of Iron Works Active.	No. of Furnaces built.	No. of Furnaces in blast.	Tons of Pig Iron made.	
ENGLAND.					
Northumberland	2	12	3	33,623	
Durham	12	76	50¼	676,964	
Yorkshire, North Riding	15	74	67	916,970	1,627,557
,, West Riding	8	38	22		77,717
Derbyshire	12	43	30		179,772
Lancashire	5	33	27	422,728	
Cumberland	7	33	24	255,178	677,906
Shropshire	8	29	22		112,300
North Staffordshire	9	36	36½		303,378
South ,, ...	56	171	114		588,540
Northamptonshire	3	10	10		43,166
Lincolnshire	3	6	4		31,690
Gloucestershire ... ... / Wiltshire ... ... / Somersetshire	6	17	12		93,601
Total	146	578	421¾		3,735,627
WALES.—NORTH.					
Denbighshire	3	8	6		42,695
SOUTH.					
Anthracite Furnaces	2	23	9	28,500	
Bituminous Coal Districts ... Glamorganshire	11	75	54	478,243	
Brecknockshire	1	17	6	472,450	979,193
Monmouthshire	10	59	45		
Total	27	182	120		1,021,888
SCOTLAND.					
Ayrshire	8	46	34		
Lanarkshire	13	92	78		
Fifeshire	2	6	3		
Linlithgowshire	1	4	3		
Stirlingshire	2	6	3		
Haddingtonshire	1	1	1		
Argyleshire	1	1	1		
Total	28	156	123		1,206,000

The summary of mills and forges in the United kingdom in operation in 1870 was—

COUNTY.	No. of Works.	No. of Puddling Furnaces.	No. of Rolling Mills.
ENGLAND—			
Cumberland	6	89	15
Northumberland	2	44	4
Durham	21	1,053	65
Yorkshire, (Cleveland)	11	529	30
,, (Leeds and Bradford)	12	236	54
,, (Sheffield & Rotherham)	10	342	55

COUNTY.	No. of Works.	No. of Puddling Furnaces.	No. of Rolling Mills.
ENGLAND (*continued*).			
Derbyshire	5	91	19
Somersetshire	1	19	2
South Staffordshire	115	1,934	307
North Staffordshire	8	406	38
Shropshire	9	206	30
Lancashire	8	192	41
NORTH WALES—	3	54	6
SOUTH WALES—			
Glamorganshire	17	568	90
Brecknockshire	1	62	9
Monmouthshire	12	535	45
SCOTLAND—	14	339	41
	255	6,699	851

The following is the list of works having Bessemer converters in Great Britain in 1870:—

Name and Situation of Works.	No. of Converters.	Capacity. Tons.	cwt.
Henry Bessemer & Co., Sheffield	2	4	0
	1	–	10
Jno. Brown & Co., Limited, „	2	10	0
	2	5	0
	2	3	0
Charles Cammell & Co., Limited, Sheffield	8	5	0
Weardale Iron Co., Towlaw	4	2	10
J. M. Rowan & Co., Atlas Works, Glasgow	1	3	0
Samuel Fox & Co., Deepcar	2	3	0
Lloyds, Foster & Co., Old Park, Wednesbury	4	3	0
Bolton Iron and Steel Works, Bolton	4	6	0
London and North Western Railway, Crewe	2	3	0
Lancashire Steel Works, Gorton	2	6	0
Mersey Steel and Iron Works, Liverpool	2	5	0
Manchester Steel and Railway Plant Co., Gibraltar Works, Newton Heath, Manchester	4	3	0
Barrow Hematite Steel Co., Barrow	6	6	6
	6	5	10
Dowlais Iron Co., Dowlais	6	5	0

Name and Situation of Works.	No. of Converters.	Capacity. Tons.	cwt.
Ebbw Vale Iron Co., Ebbw Vale	7 ...	5	0
Bessemer and Sons, Greenwich	2 ...	5	0
West Cumberland, Workington*	– ...	–	–
Phœnix Iron Co., Rotherham	2 ...	4	0

Bessemer Works in other countries, 1868 :—

In United States of America	7 works
„ France	5 „
„ Belgium	1 „
„ Prussia	7 „
„ Austria	10 „
„ Sweden	12 „
„ Russia	1 „
„ India	1 „

The returns received from 33 tin-plate works, which have furnished returns, have been—

Number of boxes of tin plates	1,818,832
„ terne plates	148,221
„ black plates	27,729
Total number of boxes	1,994,782

There is the produce of 24 works to be estimated, and these, it is calculated, will give—

Number of boxes of tin plate as	1,345,000
„ terne plates	120,000
Total estimated	1,465,000
Total returns	1,994,782
Total produce of boxes of tin and terne plates in Great Britain during 1870 ...	3,459,782

The summary of coal produced in the United Kingdom was as below :—

	Tons.
Durham and Northumberland	27,613,539
Cumberland	1,408,235

* Four of $7\frac{1}{2}$ tons each are being constructed.

	Tons.
Yorkshire	10,606,604
Derbyshire	5,102,265
Nottinghamshire	2,115,372
Warwickshire	647,540
Leicestershire	599,450
Staffordshire and Worcestershire	13,230,062
Lancashire	13,810,600
Cheshire	929,150
Shropshire	1,343,300
Gloucestershire and Somersetshire	1,955,910
Monmouthshire	4,364,342
South Wales	9,299,770
North Wales	2,329,030
Scotland	14,934,553
Ireland	141,470
Total Produce of the United Kingdom	110,431,192

In the Cleveland district, attention has of late been directed to improvements in the method of removing slag from the blast furnaces. For some years past the Tees Conservancy Commissioners took large quantities of slag for the construction of their breakwater at the mouth of the river. This work has now been suspended, as it has been proved that a more compact material will have to be used in the construction of that part of the breakwater more directly exposed to the action of the sea. Large quantities of slag have also been used for filling up low ground in the neighbourhood of Middlesbrough, and thus rendering it available for building purposes. There is now, however, less scope for the utilisation of slag in this manner, and blast furnace proprietors are being compelled to consider the feasibility of carrying the slag out to sea. The great difficulty that presented itself, in the first place, was to deal with the large masses in which the slag is consolidated, and which take a long time in getting thoroughly cool. This difficulty has been overcome by two plans. Messrs. Losh, Wilson and Bell, have designed an arrangement by means of which the slag, as it leaves the furnace, is run into a series of shallow trays working on an endless band. The length of band may be regulated according to the circumstances of each works, and the slag (broken and

cooled by the application of a jet of water) can be tipped into a suitable wagon, in the most convenient place. Another plan, designed by Mr. Wood, of the Tees Iron Works, accomplishes the same results by means of a shallow trough, arranged on the periphery of a revolving table. The slag is run out in a thin layer, is treated with water, and by the time it has made about half a revolution of the table is perfectly cooled, and is diverted by a scraper into a wagon, in which it can be removed. The slag when operated upon in this or some similar manner, is broken up into small pieces, in which form it can be readily tipped into barges, or put into railway trucks to be conveyed to a distance for road-making purposes. It is expected that arrangements will shortly be made for disposing in this way of the slag from a considerable number of blast furnaces in the Cleveland district.

Note.—As the publication of the Transactions of the Iron and Steel Institute ceased with Number 7, an Index for that number is sent herewith to enable members to complete their set of Transactions.

JNO. JONES.
Secretary.

MIDDLESBROUGH,
Feb., 1872.

INDEX TO VOL. II.

DOUBLE MACHINE PUDDLING FURNACE,

AND OSCILLATING FIRE GRATES,

JAMES WHITHAM, PATENTEE,

LEEDS.

Fig. 1.

SIDE ELEVATION.

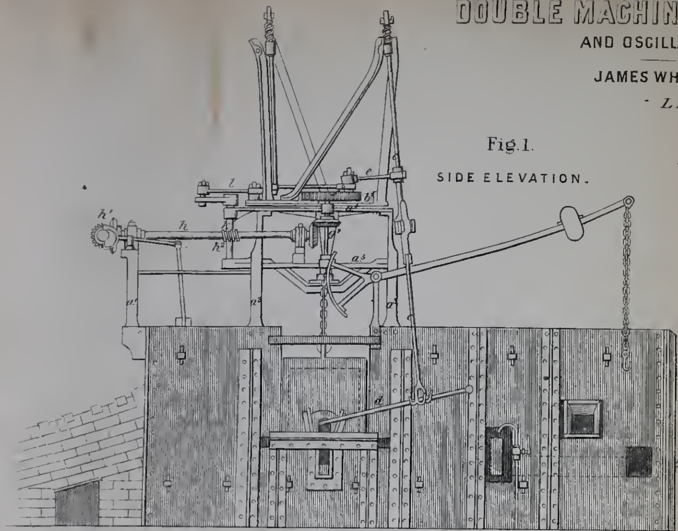


Fig. 2.

PLAN.

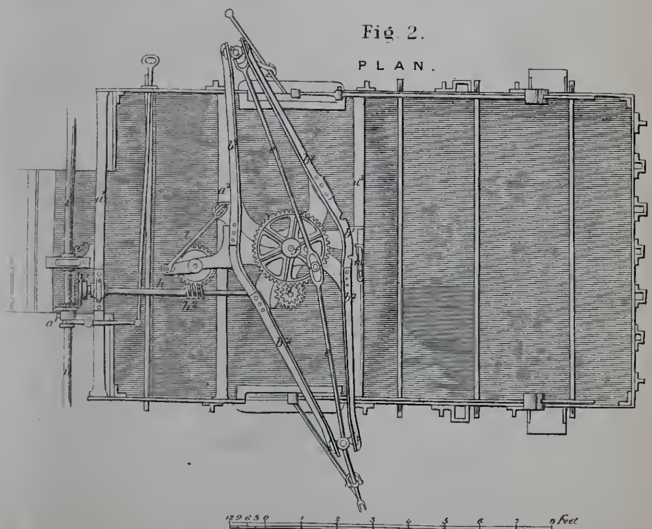


Fig. 4.

TRANSVERSE SECTION.

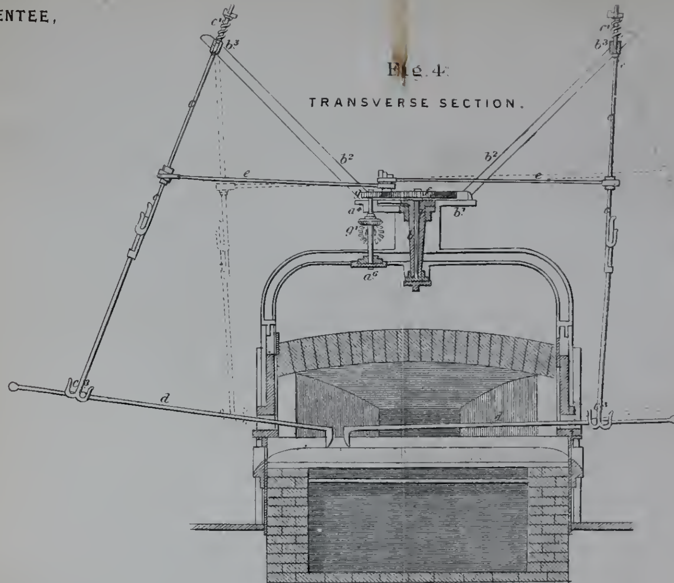
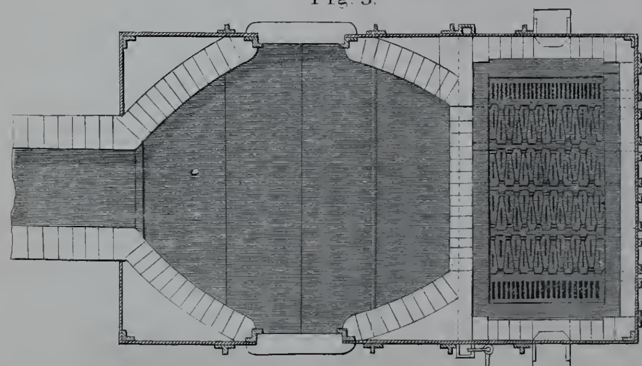
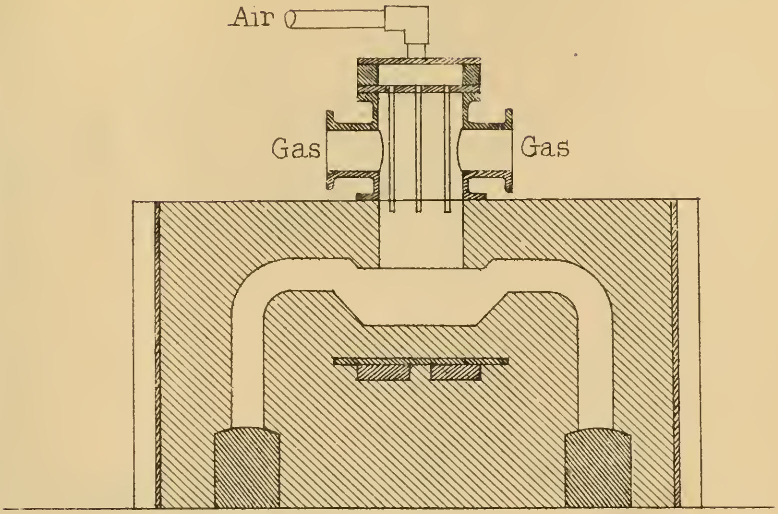


Fig. 3.



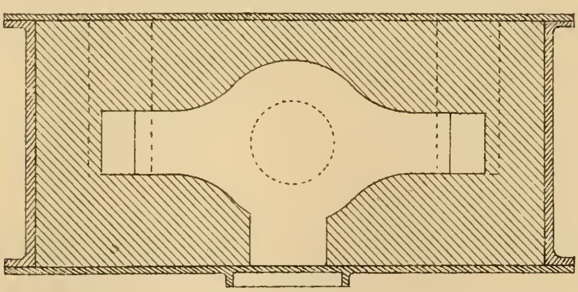
M & M W Lambert Newcastle

HOWSON'S BLOW PIPE PUDDLING FURNACE.



VERTICAL SECTION

Diameter of Hearth 2·8′
Number of Nozzles.....7
Diameter of D°. . . . 7/8″



HORIZONTAL SECTION

M & M.W Lambert. Newc

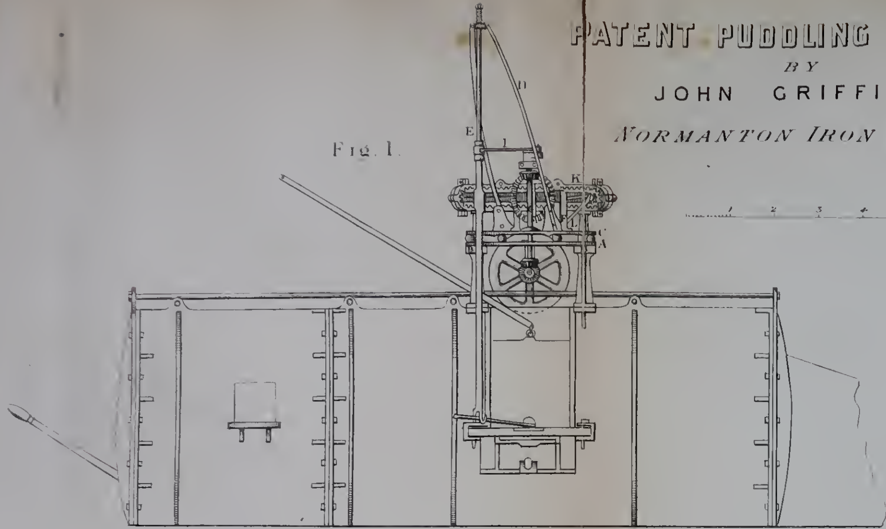
PATENT PUDDLING MACHINE,

BY

JOHN GRIFFITHS,

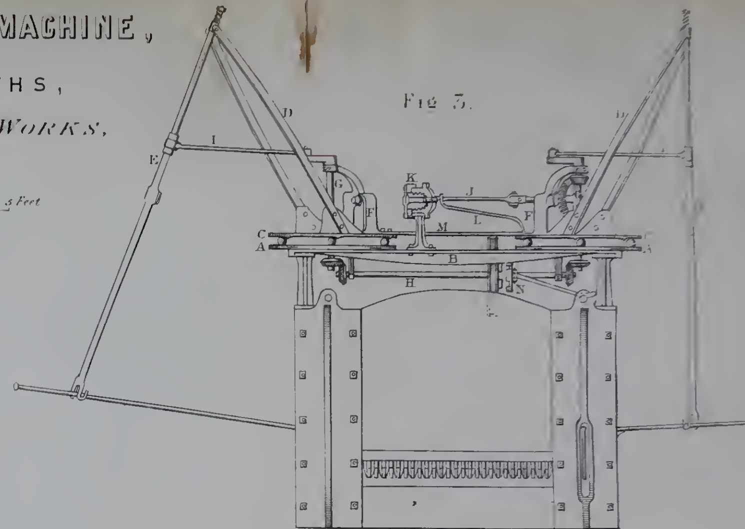
NORMANTON IRON WORKS.

Fig. 1.



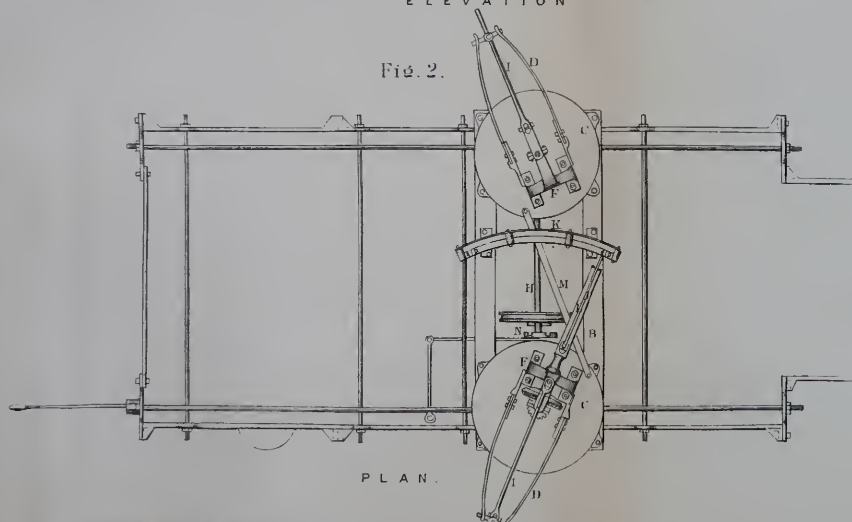
ELEVATION

Fig. 3.



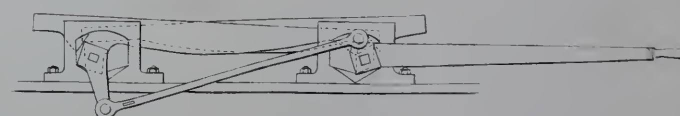
END ELEVATION.

Fig. 2.



PLAN.

Fig. 4.

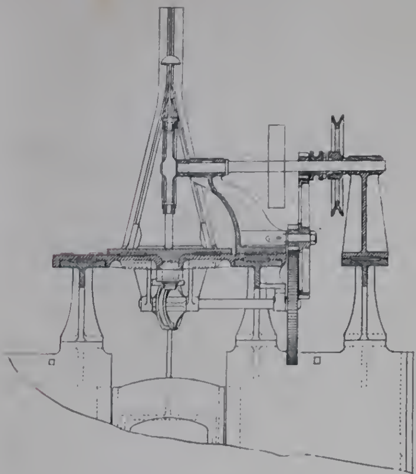


DETAIL OF FIRE-BARS.

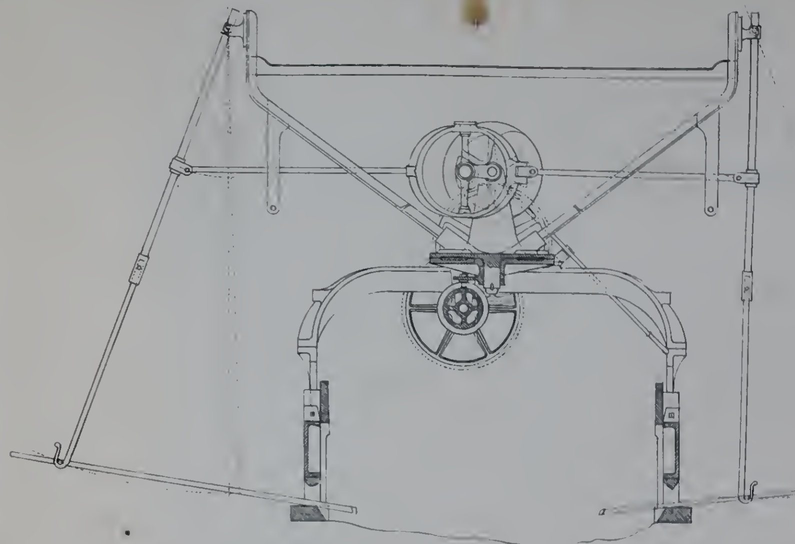
1 2 3 Feet

F. W. STOKER'S NEW STEAM PUDDLING MACHINE.

PALMER'S SHIPBUILDING & IRON COMPANY. LIMITED.
ROLLING MILLS DEPARTMENT JARROW-ON-TYNE

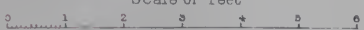


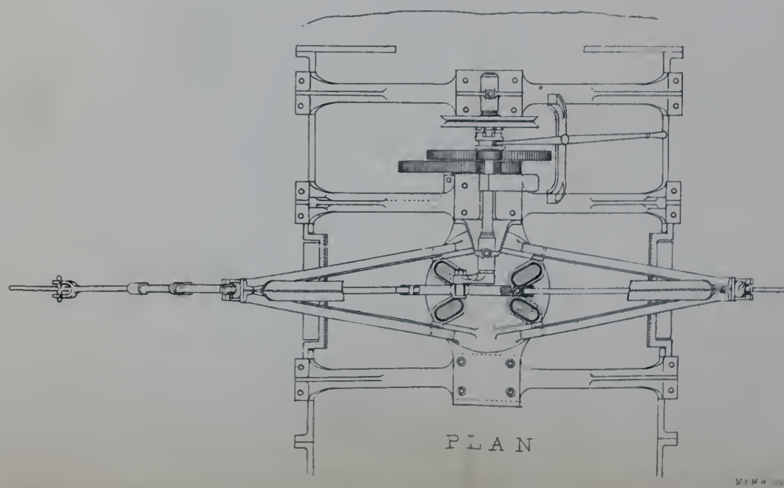
END ELEVATION



SIDE ELEVATION

Scale of Feet

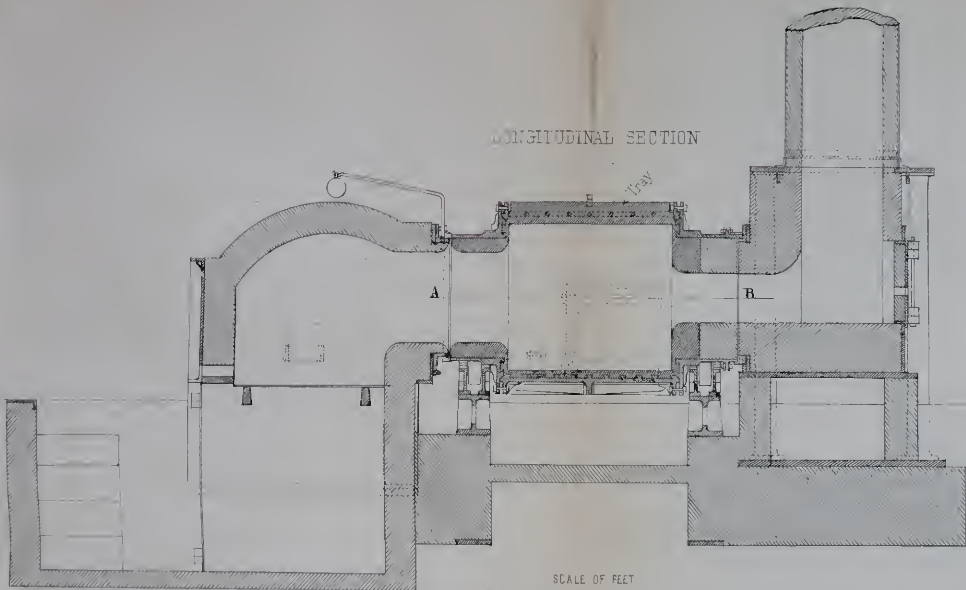




PLAN

A. SPENCER'S REVOLVING PUDDLING FURNACE.

WEST HARTLEPOOL ROLLING MILLS



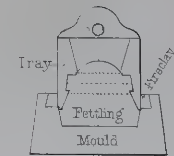
LONGITUDINAL SECTION

SCALE OF FEET

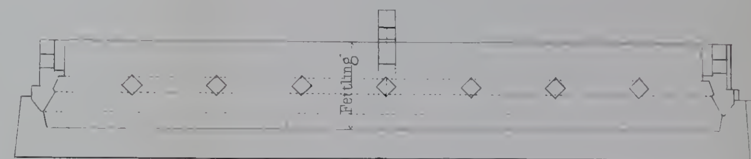
0 1 2 3 4 5

SECTIONAL PLAN AT LINE A.B

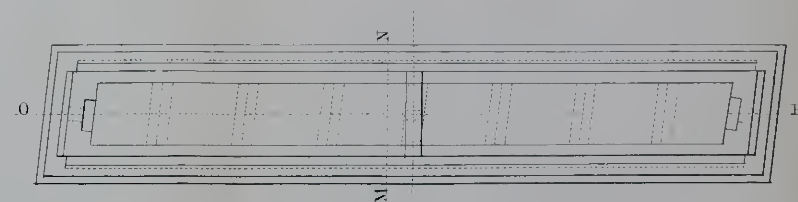
DETAIL OF TRAY AND MOULD FOR FILLING TRAYS



CROSS SECTION AT LINE M N



LONGITUDINAL SECTION ON LINE O.P.

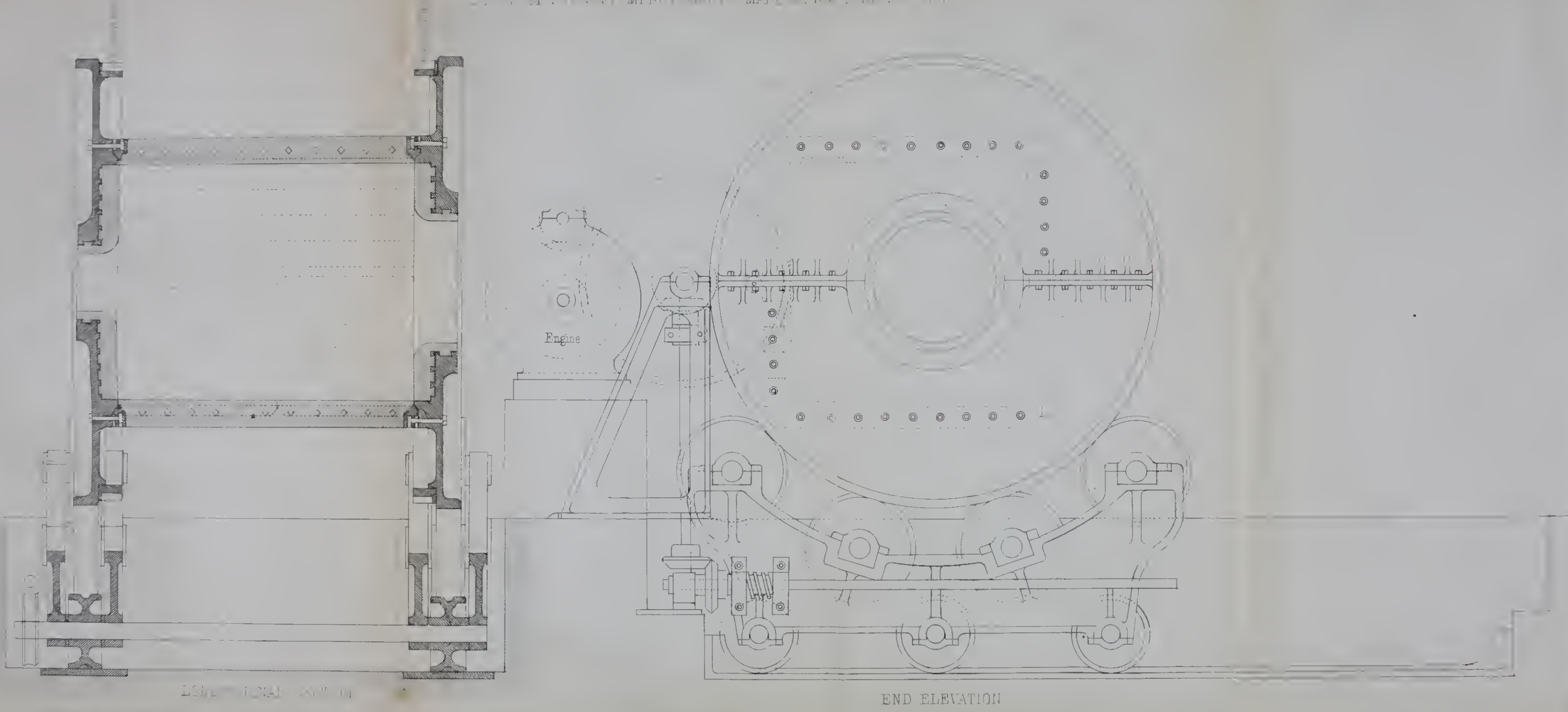


GENERAL PLAN

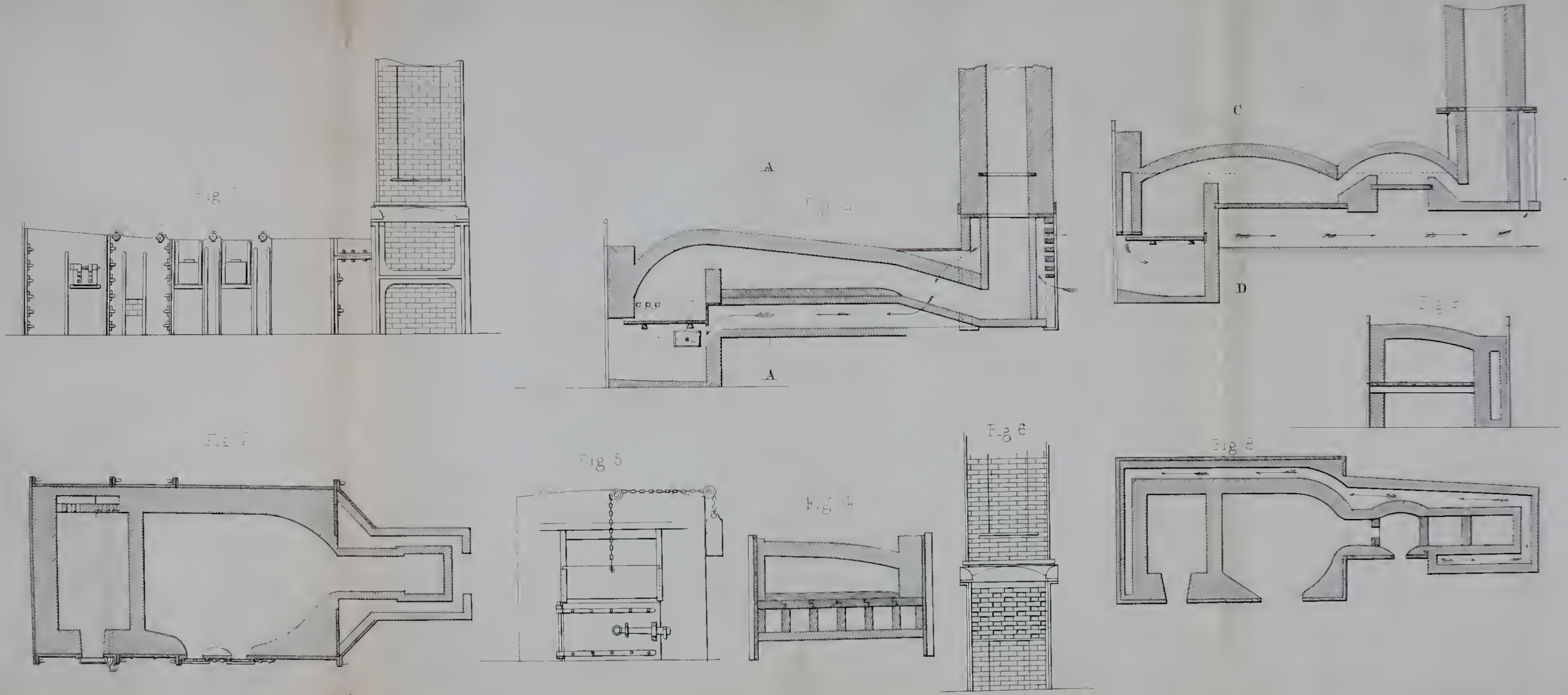
SCALE OF FEET

0 1 2

A. SPENCER'S REVOLVING PUDDLING FURNACE.



HOWATSON'S PATENT PUDDLING AND HEATING FURNACE.



MAP
OF THE
HAEMATITE IRON ORE DEPOSITS
OF FURNESS.
Upper Permian Sandstone
Magnesian Limestone
Permian
Black Shale (Yoredale Shale)
Mountain Limestone
Carboniferous
Coniston Grits & Flags
Coniston Limestone
Green Slate
Caradoc
Lower Silurian
Red Felspar Porphyry
Greenstone Porphyry & Amygdaloid
Haematite Deposits
The Numbers indicate Height in Feet above Level of Sea
SCALE
ULVERSTON
ULVERSTON CANAL
DALTON
BARROW
MORECAMBE
BAY
ISLE OF WALNEY
ISLE OF BARROW
FURNESS RAILWAY
Hare Slack Hill
Amygdaloid
Lindale
Great Urswick
Urswick Tarn
Little Urswick
Gleaston
Gleaston Castle
Stainton
Adgarley
Newton
Furness Abbey
Leece
Roosecote
Salthouse
Newbiggin
Aldingham
Baycliff
Scales
Bardsea
Sea Wood
Birkrigg Common
Sunbrick
Conishead Priory
Edge Hill
Cross Moor
Swarth Moor Hall
Low Greaves
Springfield
Dragley Beck
High Roshead
Low Roshead
Stewnor Park
Pennington
Holebiggerah
Martin
Ireleth
Ireleth Marsh
Askam Wood
Furness Iron W.
Askam Mines
Roanhead
Roanhead Crag
Roanhead Mines
Park
Park Mines
Moor Foot
Sands and Rabbit Warren
Sandscale
Sowerby Wood
Soutergate
Mill Wood
Little Mill
Breast Mill Farm
Abbots Wood
Hawcoat
Ormsgill
Cocken
North Scale
Barrow Iron & Steel Works
Newbarns
Parkhouse
Bowse Field
New Close
Dendron
Stank
Stank Mine
Holebeck
Old Holebeck
Rampside
Deep Meadow Beck
Gleaston Park
Harbarrow
Mere Tarn
Standing Tarn
Poaka Mine
Whitriggs Mines
Mousell Mines
Stainton Mines
Newton Mines
Lindale Cote Min
Lindale Moor Mines
Pennington Mine
Parkside Co
High Haume
Holmes Green
Scale Bank
Gawran
Whinfield House
Hodbarrow
Duddon Sand
North

PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

ANNUAL GENERAL MEETING, HELD IN WILLIS'S ROOMS, LONDON, MARCH 19TH, 1872.

THE President, Mr. Henry Bessemer, in opening the proceedings, said he was pleased on that occasion to see so many of the members around him. This was not a meeting in which a few comparatively idle men met together to spend a pleasant afternoon. It was a meeting for which many of the members had left important works in various parts of the country, and he felt sure that their presence in such numbers was an excellent augury for the continued success of the Institute. The progress that had been made since the first time he had the honour of addressing a meeting in that room had been very considerable. The proceedings of the Institute would be so fully set forth in the report which would be laid before the meeting, that he did not wish to occupy time in enlarging upon that point.

The President then moved that Mr. W. S. Roden, M.P., and Mr. Josiah T. Smith be appointed scrutineers for examining the voting papers for the election of new members.

The President then called upon the general Secretary to read the annual report of the Council as follows:—.

The Council have much pleasure in presenting their third annual report. They are again able to congratulate the members upon the continued success and usefulness of the Institution. This is shown by the steady increase in the number of members, and by the general interest that has been taken in the proceedings of the society during the past year. At the last annual meeting the

number of members was 347, since that time 7 have been removed from the list; the number of new members elected during the year has been 84, so that the Institute now numbers 424 members. The voting list for this meeting contains the names of 29 gentlemen who are desirous of becoming members, and since that list was sent out proposal forms for about 30 candidates for membership have been received; it will thus be seen that there is every prospect of a regular increase in the number of members.

The provincial meeting of the Institute was held at the end of August, in South Staffordshire. The business meetings were held at Dudley, and excursions were made to the most important ironworks in the district. Arrangements were also made for visiting the principal works in Birmingham, and for an excursion to Lilleshall and Coalbrookdale. The members of the iron trade in South Staffordshire and Shropshire gave the Institute a most cordial and hospitable reception, and the Council desire to record their deep sense of their obligations to the gentlemen who made the local arrangements for this meeting.

It having been intimated to the Council that the Continental ironmasters felt an interest in the proceedings of the Institute, it was decided, in August last, to issue a general invitation to the foreign iron trade to attend the present annual meeting. An official invitation was inserted in several of the leading technical journals published on the Continent and in America; in addition to which Messrs. De Laveleye and Son, proprietors of the Moniteur des Intérèts Materials, Brussels, have kindly forwarded a special circular to the principal Continental ironmasters. The Council are glad to find that their invitation has been accepted by several gentlemen extensively connected with the foreign iron trade, and in the name of the Institute they desire to welcome these members of the trade, and to bespeak for them a kind and courteous reception when they seek to visit the establishments of any of the members. The same good feeling has on many occasions been shown to individual members of the British iron trade on their visits to the Continent, and the Council are assured that the members of the Institute will rejoice to have an opportunity of receiving any representatives of the foreign iron trade who may be able to attend this meeting.

The Puddling Committee that was re-appointed at the last

annual meeting have vigorously conducted their enquiries since that time. They made arrangements with Mr. Bodmer, and (through the kindness of Messrs. Hopkins, Gilkes and Co.) with Mr. Lester, of the Tees Iron Works, Middlesbrough, to visit the principal establishments in Great Britain where improved appliances for puddling were, or had recently been in operation. The results of this enquiry have been communicated to the members in the last issue of the JOURNAL, and it is therefore unnecessary to allude to this subject in detail. Whilst these gentlemen were collecting the materials for their report, Mr. Danks came to England and submitted to the Puddling Committee particulars of his revolving puddling machine. It was felt that this was a matter of sufficient importance to be communicated to the Institute on the earliest opportunity. They accordingly suggested that Mr. Danks should read a paper at the Dudley meeting of the Institute. The statements contained in Mr. Danks's paper were generally to the effect that a considerable number of his rotary puddling machines were then in operation in America; that they gave economical results compared with hand puddling; that the yield of iron was greater; and that the quality was superior to that obtained by the ordinary process. The Puddling Committee recommended that steps should be immediately taken for testing the correctness of the statements contained in Mr. Danks's paper. The members, in general meeting assembled, approved the appointment of a properly qualified Commission, to proceed at once to the United States for the purpose of reporting upon the working of Danks's furnace. This Commission was duly nominated, and arrangements were made for their setting out early in October. They took with them pig iron selected from Cleveland, South Wales, South Staffordshire and Derbyshire, and a considerable quantity of fettling extensively used in this country. Mr. Danks accompanied the Commission, and made arrangements by which the representatives of the Institute had the fullest opportunities for conducting their experiments, and for thoroughly testing the merits of Mr. Danks's system of puddling iron. The general report of the Commissioners has been already communicated to the members; but at this meeting each of the Commissioners will make a supplementary report, which will doubtless be of great interest. The chemical analyses of Mr. Snelus will be ready for this meeting. The Council heartily endorse the views of the Puddling Committee

with respect to the very satisfactory manner in which the Commissioners have carried out their enquiry; and they desire to express, on behalf of the Institute, their best thanks to Mr. Snelus, J. A. Jones, and J. Lester, for the care and attention they have devoted to the enquiry. The Council are exceedingly glad to find that the Institute Commissioners were most cordially received by the iron trade of the United States, and they desire to tender their best thanks to Mr. Abraham Hewitt and other gentlemen who rendered material assistance to the Commission, and who in various ways assisted them in their enquiries. The further report of the Puddling Committee that will be presented at a later stage of the proceedings connected with this meeting, will give full details of the enquiries carried out under the auspices of the Institute. The Council feel that the members of the Institute are deeply indebted to Mr. Menelaus, chairman, and to the other members of the Puddling Committee, for the trouble they have taken in connection with the subject referred to them for investigation. In order to meet the heavy expenses incidental to this enquiry, and which the Puddling Committee thought should be defrayed by a special contribution on the part of the whole iron trade of the country, an appeal was made to iron manufacturers generally. This was very liberally responded to, but as the expenses have been much greater than were expected, the amount subscribed will not nearly meet the outlay. The Council would recommend that the Puddling Committee be re-appointed, and that the whole matter be left in their hands, to deal with as they may consider most desirable.

The attention of the Council has been so fully devoted to the question of mechanical puddling that no further progress has been made in reporting upon the distribution of iron ores in Great Britain. They hope to have something further to communicate on this subject at the next annual meeting of the Institute.

The Committee appointed some time ago to take action for providing house accommodation for learned and technical societies, not yet having suitable buildings in London, has during the year, made some progress; but in consequence of delays, from various causes, the proposed scheme has not yet been brought into a definite form. In case the plan should not take a practicable shape within a reasonable time, the Council will endeavour to make temporary arrangements for suitable rooms in London for the

purposes of the Institute. Papers relating to this subject will be printed as an appendix to this report.

Acting on recommendations that had received the approval of the members, the Council commenced, in February last, the periodical issue of the Journal of the Iron and Steel Institute. This has been supplied gratuitously to the members in the place of the Transactions, in which form the proceedings were at first communicated to them; but a considerable number of copies have been sold to non-members. The size of the Journal has very much exceeded the dimensions originally contemplated, but the Council are pleased to find that up to the present time, so much valuable material has been available. They feel it would be unfair did they not make special mention of the elaborate treatise on the Chemical Phenomena of Iron Smelting, that has been contributed by their colleague, Mr. Isaac Lowthian Bell. The reports of the foreign secretary have embodied particulars of all important matters connected with the foreign iron trade, and at his request, the Council desire to place on record their deep obligation to the many distinguished foreign metallurgists and men of science, who have so freely communicated most valuable information relative to the iron and steel trades in other countries.

The Council have again to report that they have received the publications and transactions of the principal scientific and technical societies in this country and on the Continent; they desire to express their thanks for these donations.

The Scotch ironmasters having intimated that they wished the next summer meeting to be held at Glasgow, the Council have accepted this invitation. A local committee has been appointed for the purpose of making the necessary arrangements, and it has been decided to hold the meeting on Tuesday, August 6th, and following days.

The retiring members of the Council are:—Vice-presidents: W. Fowler, Chesterfield; Robert Heath, Stoke-upon-Trent; F. W. Kitson, Leeds. Council: George Dawes, Elsecar; R. Fothergill, M.P., Aberdare; T. E. Horton, Shifnal; W. R. I. Hopkins, Middlesbrough; Jno. Lancaster, M.P., Wigan; but as no other gentlemen have been nominated, the retiring members are alone eligible to fill up the vacancies.

About eighteen months ago the Council were requested to make

arrangements for commemorating, in some suitable manner, the valuable services rendered to the Institute by its first president, the Duke of Devonshire. It was ultimately resolved—subject to the approval of the President—that this acknowledgment should take the form of a portrait of the Duke, to be presented to the Institute by the subscribers. This proposal having received the sanction of His Grace, a small committee was appointed to carry out the arrangements. The portrait is now completed, and the subscribers have requested that the presentation should form a part of the proceedings of this meeting. The Council have had much pleasure in acceding to this recommendation. They propose to have the portrait engraved, so that each member may be able to obtain a copy, and by the time the picture is finally in the hands of the Council, they hope to have a suitable house in which it may be placed.

In reviewing the history of the Institute, from its establishment in 1869, to the present time, the Council feel assured that the remarkable success which has characterised the movement, is sufficient evidence that a Technical Institution for the iron and steel trades was wanted. They believe that, however satisfactory the progress of the society has been up to this time, there is ample scope for a development of its operations in many directions. The Council trust that the future of this young Institution may be as successful as the past has been, and that each year will furnish it with increasing means of usefulness, and with a wider field over which its influence may be exerted.

APPENDIX TO REPORT.

HOUSE ACCOMMODATION FOR THE LEARNED SOCIETIES.

[Reprinted from the *Journal of the Statistical Society* for June, 1871.]

The following extracts appeared in the annual report of the Statistical Society, June, 1871 :—

The Joint Committee, consisting of delegates from certain of the Learned Societies, appointed to consider the best steps to be taken for the purpose of having combined and improved house accom-

modation for those bodies, have had several meetings. They have approximately determined the extent of the accommodation which they would require. In accordance with those requirements they have had a plan and estimate prepared by Mr. Thomas Bellamy, architect.

The Joint Committee, in furtherance of the object for which they were appointed, addressed a memorial to the Chancellor of the Exchequer, of which the following is a copy:—

"Statistical Society, 12, St. James's Square,

London, S.W., May, 1871.

To the RIGHT HONOURABLE ROBERT LOWE, M.P., Chancellor of the Exchequer.

The Undersigned, Members of a Committee appointed by certain Scientific and Learned Societies for the purpose of procuring the erection of a Central Building to afford a convenient place of meeting, with suitable offices and economic arrangements, for the Societies which they severally represent, and for such others as may hereafter seek the like accommodation, to the number of twelve or more,—

Respectfully request the favour of an interview, that they may submit certain facts for the consideration of Her Majesty's Government, and a proposal founded upon such facts—which proposal they venture to think will be found consistent with the interests of the public as well as with those of science and learning.

The Scientific and Learned Societies represented by the Undersigned, are prepared to raise among their members a sum of, say, £20,000, and to expend it in the erection of a building of appropriate ornamental character, which they would prefer to place on some spot bordering on the Thames Embankment, and in the neighbourhood of Whitehall.

The Societies, however, are met at the outset by a very serious obstacle, in the difficulty of obtaining a suitable site, and it is to overcome this obstacle that the Undersigned make their respectful application for the assistance of Her Majesty's Government, and venture to submit that if some portion of the space between the

Embankment and Whitehall, and having for its northern boundary Whitehall Place, were placed at their disposal on such moderate terms and reasonable conditions as Her Majesty's Government may see fit to require, the interest of Science and Learning would be materially promoted, and the site itself be so occupied as to secure the approbation of the public and harmonise with the design of the Embankment.

The Undersigned venture to hope that you will accord an early and favourable reply to this their application.

(Signed) W. A. Guy, Statistical Society.
G. W. Hastings, Social Science Association.
S. Brown, Institute of Actuaries.
A. Strange, Lt.-Col., Meteorological Society.
A. C. Humphreys, Judicial Society.
Bedford Pym, R.N., Anthropological Institute.
A. Brogden, M.P., Iron and Steel Institute.
J. Glaisher, Photographic Society.
Henry Blaine, Royal Colonial Institute.
William Newmarch, F.R.S., President of the Committee.
Frederick Purdy, Honorary Secretary."

The interview thus sought was at once granted, and Mr. Lowe expressed his readiness to forward the objects of the Committee, but referred them to Mr. Gore, the Chief Commissioner of Woods, Forests, and Land Revenues, to whose department the disposal of Crown or public lands is entrusted. The Committee are now corresponding with Mr. Gore as regards a site for the proposed building.

Note.—After leaving the Chancellor of the Exchequer, Dr. Guy and Mr. Purdy waited on Mr. Gore, who expressed himself very favourable to the object the societies had in view, but stated that the Government had not been able to decide upon any plan for the occupation of the site in question.

The President moved the adoption of the report, which was seconded by Mr. Wm. Menelaus, and carried unanimously.

The President next called on the Treasurer—Mr. David Dale—to read a statement of accounts for the year ending 31st December, 1871.

Dr. STATEMENT OF ACCOUNT FOR THE YEAR ENDED DECEMBER 31ST, 1871. **Cr.**

RECEIPTS.

		£ s. d.
To Balance in hand on Jan. 1, 1871		93 8 0
,, Cash for Journals and Transactions Sold		66 1 0
,, Entrance Fees (83 Members @ £2 2s. each)		174 6 0
,, Annual Subscriptions, viz. :—		
In respect of the year 1869 (2 Members @ £2 2s. each)	£4 4 0	
In respect of the year 1870 (8 Members @ £2 2s. each)	16 16 0	
In respect of the year 1871 (419 Members @ £2 2s. each)	879 18 0	
		900 18 0
Balance due to Treasurer		152 3 0
		£1,386 16 0

DISBURSEMENTS.

	£ s. d.
By Secretary's Salary year ended Dec. 31st	200 0 0
,, Foreign Secretary's Salary and Expenses year ended Dec. 31st	59 2 7
,, Expenses in connection with Annual Meeting in London, March, 1871	110 3 7
,, Secretary's Expenses attending Council Meetings at Birmingham	12 3 8
,, Expenses in connection with Meeting of Institute in South Staffordshire	83 18 10
,, Journal Publishing Expenses	721 11 8
,, Printing, Advertising, and Stationery	128 18 0
,, Rent, Office Expenses, Postages, &c.	70 17 8
	£1,386 16 0

ASSETS NOT BROUGHT INTO ACCOUNT.

		£ s. d.
Amount due from Authors for Reprints		17 0 0
Subscriptions unpaid :—		
Entrance Fees (2 Members @ £2 2s.)	£4 4 0	
Annual Subscriptions for 1870 (2 Members @ £2 2s.)	4 4 0	
Annual Subscriptions for 1870 (9 Members @ £2 2s.)	18 18 0	
		27 6 0
Journals in Stock on Dec. 31st, 617 @ 3s. 4d. each	102 16 8	
Copies of Transactions on Dec. 31st, 807 @ 2s. each	80 14 0	
Copies of Transactions (Bound), 6 @ 15s. each	4 10 0	
		188 0 8
		£232 6 8

DAVID DALE, *Treasurer*.

Darlington,
March, 1872.

Mr. Dale, supplementing the statement of accounts, said the Institute had in hand about £188 worth of Journals and Transactions, which had not been taken into account as assets, but they were available for sale and also for new members, who from time to time joined the Institute, and paid the entrance fee. He believed that the expenses of the JOURNAL had been exceptionally heavy during the past year, and although the statement of account which he had just read showed that the expenditure had somewhat exceeded the income, he thought the number of members then proposed for admission would in all probability create a proper relation between the expenditure and the receipts.

On the motion of the President, seconded by Mr. W. Jenkins, the Treasurer's Report was received and adopted.

The Scrutineers reported that the following were duly elected members. :—

Adams, John	Hollinswood, near Wellington, Salop	General Manager, Eagle Iron Works.
Ainsworth, George ...	Consett, Blackhill, Co. Durham	Analytical Chemist in Iron Works.
Alexander, Edward ...	Hartlepool	Iron Shipbuilder.
Beaumont, Capt. F.E.B., (M.P.)	London	
Brown, George	Atlas Works, Sheffield ...	Steel Manufacturer.
Cabry, Charles	York	Engineer to N.E. Railway.
Chatelier, L. le	33, Rue Madame, Paris ...	Ingênieur-in-chef du Mines.
Criswick, Theophilus ...	8, Gore Terrace, Swansea ...	Engineer.
Daglish, Robert ...	Aston Hall, near Preston Brook, Cheshire	Ironmaster and Ironfounder.
Ellis, Thomas	Coatbridge, N.B.	Iron Manufacturer.
Faviell, Jeremiah B. ...	Campsmount, Doncaster ...	Director of Norwegian Titanic Iron Company, Stockton.
Gowen, Franklin B. ...	Philadelphia, U.S.A. ...	President of Philadelphia and Reading Railroad.
Hackney, William ...	Landore, Swansea	Manager of Steel Works.
Hosking, Richard ...	Dalton-in-Furness	Manager of Iron Mines.
Humphreys, A. W. ...	42, Pine Street, New York	Manager of Iron Works.
Kitching, Alfred ...	Darlington	Ironmaster.
Leonard, Moses	N.B. Ironworks, Coatbridge, N.B.	Manager of Iron Works.
Millington, Samuel L. ...	Summerhill Iron Wks, Tipton	Ironmaster.
Morrison, H. M. ...	Wellington Place, Longsight, Manchester	Mining Engineer, &c.
Nelson, Thos. Bowstead	York	Engineer.
Pearse, Mountjoy ...	Stockton-on-Tees	Iron Shipbuilder.
Parker, Jno. Spear ...	Cyclops Steel Wks, Sheffield	Analytical Chemist, &c.
Sparrow, Arthur ...	Penn, Wolverhampton ...	Ironmaster.
Stoker, F. W.	The Moor Iron Works, Stockton-on-Tees	Engineer at Iron Works.
Summers, James W. ...	Globe Iron Wks, Staleybridge	Manager of Iron Works.
Thompson, George ...	Winlaton, Blaydon-on-Tyne	Engineer & Managing Partner in Forge & Chain Manuf'cty.
Walker, Alfred	York	Engineer & Managing Partner in the York Rlw'y Plant Co.
Webb, Henry A. ...	Bretwell Hall Iron Works, Stourbridge	Iron Manufacturer.
Williams, Nicholas ...	Hodbarrow Iron Ore Mines, Holborn Hill, Cumberland	Engineer, &c., at Iron Mines.

Lord Frederick Cavendish moved the first resolution, which was as follows:—

"That the best thanks of this meeting be and are hereby given to the President and Council for their valuable services during the past year." His Lordship said the report which had been just read, and the Journals which had been issued, and which he thought most of the members must have studied to their advantage, were the best proofs of the useful work that had been done by the President and Council during the past year. He felt sure that every one present would join most cordially in the vote of thanks which he proposed.

Mr. Ramsden had much pleasure in seconding the proposition that the best thanks of the meeting be given to the President and Council. It must be plain to every member of the Institution that the very able manner in which the Council had performed their duty in the past, had been the means of placing the Institution in its present position. He thought he was justified in saying that few Institutions had risen so rapidly to success as the Iron and Steel Institute, and that fact was due, principally, to the manner in which the affairs of the Institute had been conducted by the President and Council.

The resolution was carried by acclamation.

The President, in returning thanks on behalf of the Council, said he could personally claim very little credit for having conducted the affairs of the Institution to their present successful issue. Whatever he had done had been warmly seconded and ably assisted by the Council and officers of the Institute, whose labours, he might say, had been unremitting, and whose attendance at all the necessary meetings had been very regular. He was sure that he spoke the sentiments of the Council, as well as his own, when he said that there was no matter that they had more at heart, or which was more strongly felt by them, than the success of the Iron and Steel Institute, and no interest that they took in any other of the various matters in which they were engaged afforded greater pleasure to them than to see the rapid progress that had been made in developing the Society. However slightly he might have helped towards that end, the labour had been one that had yielded him a great deal of pleasure. He begged to thank the members for the kind way in which they had expressed their approval of what had been done, and he hoped that in the future what efforts he might

be enabled to make in connection with the Institution, would meet with the same meed of praise.

Mr. I. Lowthian Bell, in proposing the next resolution, said the office of a Treasurer was usually more or less of a purely honorary description. It consists for the most part of receiving the sums of money which were offered for his acceptance, and discharging the claims which were made upon the Institution on behalf of which he acts; but the Treasurer of this society had undertaken his duty with an amount of zeal which far exceeded that usually displayed by gentlemen holding similar positions elsewhere. He had not only had to keep a correct account of the income and expenditure, but he had had another obligation of no ordinary character to those which they owed him as members of the Iron and Steel Institute; for instead of the Treasurer having had the use of their money, they had during the past year been indebted to him to a considerable extent. Under these circumstances, he thought that if ever a Treasurer deserved the thanks of those on behalf of whom he acted, their Treasurer was pre-eminently entitled to them. He moved "that the best thanks of the meeting be and are hereby given to Mr. David Dale for the services he has rendered the Institute since its establishment, as Treasurer."

Mr. Josiah Smith, in seconding the vote of thanks to Mr. Dale, said he was quite sure every member felt that the Treasurer was specially entitled to the best thanks of the Institute for the able manner in which he had performed the duties of the office.

The resolution was carried unanimously.

Mr. Dale wished very briefly to acknowledge the manner in which they had so kindly thanked him for the services that he had rendered. Certainly, he thought he should not be wanting in that description which Mr. Bell had given of a Treasurer's duty, in accepting those sums of money offered to him, and he only hoped that they would be offered punctually.

The President said the next matter he had to propose was the re-election of the retiring Vice-Presidents and members of the Council. There appeared to be so unanimous an opinion that all those gentlemen were well qualified in every way to fulfil the office that they had kindly undertaken hitherto, that no one had stepped forward in competition to fill the vacancies formed by the usual retirement in accordance with the rules.

The resolution was carried unanimously.

His Grace the Duke of Devonshire said, the resolution which he had to propose was as follows:—"That the cordial thanks of the meeting be and are hereby given to Mr. Menelaus, as Chairman, and to the other members of the Puddling Committee, for the trouble they have taken in connection with the enquiries they have so ably conducted during the past year, and that they be requested to continue their services during the current year." This was a resolution which he had great pleasure in proposing, both because he entirely concurred in it, and because he felt that it needed very few words by way of preface to recommend it for their adoption. He recollected three years ago, when he had the honour of delivering the inaugural address at the first meeting of the Institute, that he had occasion to allude to the subject of puddling, and he referred to it as being the most severe form of labour known in any branch of industry; at the same time also, he took occasion to observe that, so far as their prospects enabled them to form an opinion at that period, there was but very little hope that it would be superseded by mechanical puddling. But what was then looked upon as a rather improbable contingency, had, he was happy to say, in the interval, become an established fact. They were aware that the practice of mechanical puddling was quite established, but he did not think that it had been sufficiently investigated from a financial point of view, and it yet remained, probably, still to be ascertained, whether or not it could be advantageously introduced in any or in all circumstances. However, in reference to this subject, they would all cordially agree in the motion which he had to propose. The Institute was under the very greatest obligation to Mr. Menelaus and the other gentlemen who had devoted so much care and attention and labour to the investigation of the various systems which had been proposed for this purpose, and they would not hesitate in agreeing to the vote of thanks he wished to propose. There was much yet for them to do. They, therefore, begged not only to thank them for their past services, but to express a hope that they would be so good as to continue those services for another year.

Mr. Walter Williams briefly seconded the resolution, which was carried unanimously.

Mr. William Menelaus said that in the name of the Puddling Committee and himself, he thanked them very heartily for the

compliment which had been paid to them, and he promised that they would pursue their investigations, during the current year, with the same earnestness that they had done for the previous two years.

Mr. Edward Williams proposed the following resolution :—"That the Institute desires to record its high appreciation of the very satisfactory manner in which Messrs. George J. Snelus, Jno. A. Jones, and J. Lester carried out the investigation entrusted to them, in reporting upon the working of Danks's rotary furnace in America. That the best thanks of the Institute be also accorded to the Proprietors of the Cincinnati Iron Works, and to many other gentlemen in the United States who rendered much assistance to the Commissioners in the prosecution of their enquiry. Also, that Messrs. Bodmer and Lester be thanked for the care they have bestowed in reporting upon the question of improved arrangements for puddling in connection with the ironworks in the United Kingdom." If the gentlemen who went to America had come back with an unfavourable report they would still have been very much indebted to them, because it was no slight sacrifice to Mr. Snelus, Mr. Jones, and Mr. Lester to leave their ordinary avocations and to go for months to a country far away, for the purpose of investigating a matter of general interest to the iron trade; but they had not come back with a discouraging report; on the contrary, they had returned with one of a very favourable character, and while it could not yet be said that the question of mechanical puddling was absolutely set at rest, there was such a prospect of its being achieved as ought to be very gratifying to the trade. The financial part of the matter had not yet been enquired into, but this he looked upon as a minor part of the question. If puddling could be done at all—at any reasonable price—without the hard labour at present necessary for it, he thought it would be to the trade, and to the world at large, a very great advantage. They should at least know that at some price or other the work could be done. At present there was a growing disinclination among men to take to puddling as a business, and having been all his life amongst puddlers, he was not very much surprised at this feeling. Puddling was not only *not* better done now, but he thought it was not so well done as it was 20 years ago. This was not because working men were getting worse in quality—on the contrary, as a rule, he believed they were getting much better—but because the best men and the most prudent men among

workmen declined to undertake this excessively laborious work of puddling; they, therefore, went off into other lines of business. Considering all the trouble that these gentlemen had taken, and considering, in addition, that they had brought back so satisfactory a report, the meeting would cordially give them a vote of thanks. As regards Messrs. Bodmer and Lester, they too had taken a great deal of trouble, but they were rather in the unfortunate position of having been eclipsed by the very much more important invention which had come from America, but notwithstanding all that, they had served the Institute efficiently. They could not, therefore, do otherwise than include them in the vote.

Mr. Thomas Bell, in seconding the vote of thanks proposed by Mr. Williams, said he was sure everyone who had read the report must be satisfied that the gentlemen named in that resolution had done their work exceedingly well, and in such a manner as to entitle them to the best thanks of the Institute.

The resolution was carried unanimously.

Mr. Snelus said that, on behalf of himself and the other gentlemen named in the resolution, he had much pleasure in acknowledging the vote of thanks. It would be useless for him to say that they had had no hard work about it, but they had also had a good deal of pleasure, and their trip to America would be long remembered by each of the Commissioners, on account of the very kind manner in which they had been received there by all interested in the iron trade, and also by other gentlemen who were very distantly connected with it. Their reception was altogether highly satisfactory. He should have, and his fellow Commissioners would also have to present to the meeting, a supplementary report upon the process of mechanical puddling, and he was happy to say that, as far as his own report was concerned, it was perfectly satisfactory.

Mr. J. A. Jones briefly acknowledged the vote of thanks.

The President said it would be within their remembrance that a committee was last year re-appointed to report on the distribution of iron ores. The labours of that committee had to a certain extent gone on, but owing to the very interesting question of mechanical puddling occupying so great an amount of the attention of the Council, it was found almost impossible to proceed with the former investigation in a way that would be satisfactory. However, it is now thought desirable to resume those operations, and he, therefore,

proposed "That the committee elected to report on the distribution of iron ores be re-appointed."

The resolution was duly seconded and carried.

Mr. W. R. I. Hopkins said the resolution entrusted to him was as follows: "That this meeting desires to record its obligations to Messrs. De Laveleye and Son, and to Mr. Deby, of Brussels, for the trouble they have kindly taken in bringing under the notice of the Continental iron trade the invitation of the Council to gentlemen connected with the iron and steel trades of the Continent to attend the present annual meeting of the Institute." He was sure they would all feel that it was both their duty and their pleasure, to endeavour to raise an interest in the minds of their Continental neighbours in reference to the proceedings of the Institute. The gentlemen whose names had been read, had taken a great deal of trouble in this respect, and had done all they could to bring their proceedings before the Continental members of the iron trade. The consequence was that they had a goodly gathering of their number at that meeting. They might also, in the future, have to call in the aid of their friends, Messrs. De Laveleye and Son and Mr. Deby, because it was not unlikely that they should pay a visit to the Continent in one of the summer expeditions. Therefore, they should record their appreciation of the assistance these gentlemen had done in the past, for what they were doing in the present, and what they might do in the time to come.

Mr. D. Forbes (Foreign Secretary) was happy to say, in reference to the subject introduced by Mr. Hopkins, that they were likely to have a good number of representatives at the conference in connection with both the iron and steel trades of the Continent. He had then the names of no less than nineteen foreign gentlemen, who represented nearly all the nations in Europe, and who represented also some of the most distinguished firms on the Continent. He had received from a very large number of gentlemen answers, the tenor of such answers being that they regret they had not been able to come, or that they regret their absence because of their want of a better knowledge of English, but they hoped at some future time to attend the Institute meetings. All of them cordially expressed their interest in the objects of the Association. Some of them also hoped that they would have the pleasure of seeing the members of the Institution in France and in Germany. He had

no doubt before long they would have a number more present, and they were very much indebted to Messrs. De Laveleye and Son and to Mr. Deby, for having brought this matter to the knowledge of the iron masters on the Continent.

The resolution was carried unanimously.

Mr. Deby said he would express himself in English as well as he could. Mr. De Laveleye and himself had to thank them very much indeed for their kind expressions. In exchange for them all, he begged to say that they would do all they could in the future to be of any use to the Institute, and if the members came to the Continent, they would certainly open their doors as hospitably as the English ironmasters had done to the Continental visitors, and more than that he thought they could not offer.

The business proceedings of the meeting then terminated.

PRESENTATION TO THE INSTITUTE OF A PORTRAIT OF HIS GRACE THE DUKE OF DEVONSHIRE.

Immediately after the termination of the proceedings connected with the annual meeting of the Institute, the subscribers to the portrait of the first President—the Duke of Devonshire—held a meeting for the purpose of presenting to the Institute the portrait of his Grace, that had been painted for the subscribers by Mr. H. F. Wells, R.A.

Mr. I. Lowthian Bell said, in obedience to the call of the Portrait Committee, he had much pleasure in laying before them a very brief account of the duties—as they had performed them—in connection with the portrait, which was then, for the first time, presented to their notice. He was sure that those who, in the first instance, were sanguine enough to anticipate for the Iron and Steel Institute a brilliant future, had ample cause to congratulate them-

selves on the results of their labours, as they had been detailed in the report of the Council read that morning. His friend, Mr. Forbes, had confirmed that opinion by showing the interest felt by their continental colleagues in the iron trade in the proceedings. It had been stated that there was an Englishman who was so ardent an admirer of that brilliant work from the pen of Cervantes, that he declared his intention—an intention which he (the speaker) believed he carried into execution—of learning the Spanish language, in order that he might be able to read that almost unparalleled history of Don Quixote in the language of the original. On Mr. Forbes's testimony on that occasion, they must believe that their continental friends attached so much importance to what the Institute had done, and what it promised to do, that the reason why many of the foreign ironmasters were deferring their visit to this country, to attend the meetings of the Institute was, that they might learn a little more English, in order more thoroughly to follow and appreciate the proceedings. The object the members had in view in establishing the Iron and Steel Institute was, if possible, to awaken in the minds of those who carried on the iron trade of this country, a proper appreciation of the great importance of applying science to that great branch of industry to which they devoted themselves. He thought that the promoters had been fairly successful in that respect. The papers submitted for their consideration, at the various meetings, included schemes intended to advance the science of iron metallurgy, which only required ordinary intelligence—combined, perhaps, with extraordinary experience—to show the fallacy, at all events, of some of those proposals. To expose fallacies was, no doubt, far from being an agreeable office, but, as he had said on a previous occasion, it was one of some value, not only to them alone, but to those who propounded them, and he believed that it was of the greatest possible importance, that those who undertook to teach the trade, should be warned of their error as speedily as possible. Fortunately, it fell to their lot occasionally to have to discharge a duty of a very different character, and he trusted that such might be the case in reference to the report emanating from the Puddling Committee. Under those circumstances of self-congratulation it was not to be wondered at that the founders of the Iron and Steel Institute should be very wishful to take some steps in order to commemorate

the establishment of a society, which, he believed, was calculated to afford very great benefit to the members, to the country at large, and, he might say, to civilization generally; for in promoting efficiency in the manufacture of iron, who could ascribe a limit to the effect produced on the welfare and comfort of the human race? Whilst they were anxious to possess some record of the formation of the Institute, they were also most anxious not to lose sight of one fact, which, he believed, had greatly conduced to place the Institute upon a footing of unmistakeable honesty of intention and future usefulness. The fact to which he alluded was, their having succeeded in inducing the nobleman on his left hand to undertake the very responsible and onerous position of recommending the Iron and Steel Institute—not to the iron trade of one district of the empire, but to every branch of it, in every portion of the kingdom. He did not know that they could have been more fortunate in any respect in their choice. They were anxious so far as they could to recommend the application of science to the art of iron making. If they had sought the country through it would have been impossible to have found a family within which could be ranked a more illustrious name than that of Cavendish, for, so long as science was venerated in this country, and in the world generally, the great name of Cavendish the chemist, could not, and never would, be forgotten. But that was not the only reason which guided the founders—if he might so term them—of that Institute in making the selection they did, when they asked his Grace the Duke of Devonshire to undertake the office and duties of their first President. His Grace himself, as was well known, ventured of his own free will into an arena where neither ancestors nor lineage could procure any advantage, and then by the exercise of his own intelligence and industry, he obtained the highest meed of approbation and honour, which it was in the power of their universities to bestow. His colleagues and himself conceived that there was no man in the kingdom, as regarded the scientific view of the question, more fitted to undertake the duty than his Grace the Duke of Devonshire. There were many men in the position held by his Grace who preferred learned ease to undertaking the more active and onerous responsibilities of life. His Grace, however, had acted differently. He had not shrunk from undertaking the duties and responsibilities connected with the initiation and development

of certain great branches of industry in this country, and in promoting industry. He was sure he was correctly interpreting the sentiments of his Grace when he (Mr. Bell) said that the Duke felt he was adding lustre to his already brilliant name by so doing. Here it was that they felt that the qualifications and antecedents of his Grace fitted him well for the position they desired him to fill; but it remained for the Duke himself to substantiate and make good the expectation which they had formed in respect to the discharge of the duty he had kindly undertaken. Upon that he would not dwell at great length, for they were aware how admirable his conduct was while occupying the office of first President. They would remember tbe great interest the Duke felt in every matter coming before the Institute, how well he directed their discussions, and how patiently he listened to their observations. With these few remarks (which he would scarcely have ventured to submit to the meeting had he not known that the members were as well acquainted as himself with the circumstances which led to his addressing them upon that occasion) he begged, on behalf of the subscribers to the portrait of his Grace, to tender to the members of the Iron and Steel Institute the work itself as a gift, in commemoration of the important services rendered by the Duke of Devonshire, and he trusted that before long they would have established for themselves "a local habitation" as well as "a name," (for the name he trusted they had already established.) In that habitation they could place that fitting record of their appreciation of his Grace's conduct as their first President.

The President said, that on that occasion he had the honour of representing in person the Iron and Steel Institute. They had received a gift which, he was sure, every member present would appreciate to its full extent. Most of the members had seen the commencement, in some shape or other, of similar Institutions, some of which might have slowly and steadily progressed, while others had to struggle incessantly against difficulties, and had required years for a partial development even. That, fortunately, had not been the case with the Iron and Steel Institute, for they had the advantage of highly practical men to assist in the formation of that Society—men connected with every branch of the manufacture to which the Institute was devoted. They had also the good fortune of having associated with them, as the first President

of the Institution, the nobleman on his right hand. He was sure they would agree with him, that the amount of success they had already achieved, and the position which he hoped they would ever hold before the world in general, was mainly due to the unremitting care and attention of the Duke of Devonshire, in the early stages of the Institution, and he felt assured that the iron masters and steel manufacturers of the kingdom would ever retain a grateful remembrance of the kind sympathy and of the encouragement which they had received from his Grace on all occasions. He felt that after what had fallen from Mr. Lowthian Bell upon the subject, he should be trespassing were he to attempt to amplify what had been so ably said; but he was sure he expressed the entire feeling of all present when he tendered to the subscribers, who had kindly presented that portrait, the cordial thanks of the Institute, and he did not hesitate to say that nothing could have been given to that young Institution, which would have afforded so much pleasure and so much gratification, and could have done so much honour to its members. He hoped, as his friend, Mr. Bell, had previously remarked, that the time was not far distant when, in the building to be devoted to this special Institution, the portrait of his Grace might take its proper place. Before that time they might hope to see it exhibited in the Royal Academy, and he trusted also, that when an engraving of it should be executed, every member of the Institute would have the pleasure of having, in his own house, a copy of a painting representing a nobleman so highly esteemed and respected by every member of the Institute. He had, in conclusion, formally to tender the hearty thanks of the Institute to the gentlemen who had so kindly presented the portrait to the Iron and Steel Institute.

His Grace the Duke of Devonshire (who, on rising to address the meeting, was received with great applause,) said, they would readily understand that he was desirous to address a few words to the members of the Institute before the proceedings of that afternoon were brought to a close, upon a subject in which he was personally so closely concerned. He found himself, however, in a position of considerable difficulty, that difficulty being increased, in no small degree, by the terms in which Mr. Lowthian Bell had offered the portrait for the acceptance of the Institute. He, therefore, found it by no means an easy task to avail himself of words that were adequate to express his sense of the honour which had been con-

ferred upon him, by the very great kindness which had prompted the members of the Institute to desire that the memory of his connection with it, as its first President, should be perpetuated by the portrait which had then become its property. It was necessarily very gratifying to him to have received a compliment of so marked a character—a compliment conveying to him the assurance that the members of the Institute retained an agreeable recollection of the time when he had the honour to preside over its meetings. But they must permit him to add that he could not regard the proceedings of that day simply, or even principally, from a point of view personal to himself. It seemed to him that the portrait, as had been intimated in the opening remarks of Mr. Bell, might very properly be regarded as constituting a permanent record of the foundation of the Institute, an event which, he believed, would always be remembered as an important era in the history of the iron trade. As they were only just concluding the third year of their labours, it was perhaps somewhat premature to picture to themselves the sentiments which would be entertained by the members of the Institute hereafter. Still he thought he might venture to anticipate that, as time went on, it would be a matter of interest to the members of the Institute to be reminded, by the possession of that portrait, of the origin of the Institute, and the circumstances which in the year 1869 induced a great body of the members of the iron and steel trades of the country to concur so cordially in the scheme for establishing it. He believed it was known to some that the distinguished artist (whose work he hoped would be generally approved) would himself have desired to give the portrait a more entirely distinctive character than it possessed —such a character as he had referred to—but it was found upon consideration that there were insuperable difficulties in the way of carrying out that scheme, and, therefore, the idea was necessarily abandoned. He would not, however, pursue that topic further; but before he concluded, he must be allowed to take that opportunity of expressing the great pleasure and satisfaction it had been to him to find himself associated with a body of gentlemen who had, in carrying on the work of the Institute, not only displayed so much ability, and co-operated with each other in so enlightened and liberal a spirit, but had steered clear in their proceedings of all unworthy jealousy (of which indeed there had

been no trace), and had allowed no narrow views of supposed self-interest, on any occasion, to interfere with the work which the Institute was founded to carry out. They had come forward and had been influenced by one general desire to add to the common stock of knowledge applicable to the improvement of that great branch of national industry. He believed that in those few words he expressed sentiments and views which would be generally agreed to by the members of the Institute, and he would only add that so long as that spirit continued to animate those who conducted the proceedings of the Institute, he felt that the organization would be a powerful instrument for the advancement and progress of the iron and steel trades of Great Britain. He would not trouble them with any further remarks except to express again his most cordial thanks to them for the great honour which had been conferred upon him by the proceedings of that day.

Mr. Fothergill, M.P., thought they ought not to separate without passing a vote of thanks to the Committee, who had taken so much pains and trouble in carrying out the wishes of the subscribers. Their best thanks were due to Mr. Bell, Mr. Dale, and the other members of that Committee for their services in this matter.

Sir John Alleyne, in seconding the vote of thanks, would impress upon the members of the Institute that, as they represented the main staple trade of the country, they ought to have a good house in which to place their portrait, and if the Committee who had charge of that subject—and individual members also—would continue to give their attention to the matter, he ventured to think that it would not be long before they had suitable rooms for the purposes of the Institute. He had great pleasure in seconding the vote of thanks.

The resolution was carried unanimously.

Mr. I. Lowthian Bell returned thanks on behalf of the Committee.

WEDNESDAY, 20th March, 1872.

The President, in opening the proceedings, said the first business would be to read one of the papers left over from the Dudley meeting.

ON THE NEWPORT PUDDLING FURNACE,

By MR. JEREMIAH HEAD, Middlesbrough.

It may seem presumptuous on my part to bring forward a paper upon a non-rotary puddling furnace, at the present moment. No iron manufacturer can be more impressed than I am in favour of the system which has been investigated by our American commission, and no one will more heartily rejoice at the final and complete success of mechanical puddling. I need hardly remind you, however, that my paper was written before we had any definite information in respect of Mr. Danks's invention; and it was my misfortune, and not my fault, that lack of time excluded it from consideration at our Dudley meeting.

Under these circumstances, I had almost made up my mind to withdraw it altogether, but the officers of the Institution encouraged me to proceed, after a recent perusal, and, as I understand, for the following reasons, viz.:—

Firstly,—The paper contains certain original experiments and investigations hitherto unrecorded, and which are as applicable to any form of furnace for heating purposes, or possibly, even to that which rotates, as to the old-fashioned appliance, the doom of which seems to be sealed.

And, secondly,—At a time when the minds of iron manufacturers are occupied in estimating the commercial value of the new system it is fair that comparisons should be made with the most efficient furnaces now in regular use, and not only with the least favourable specimens.

Every one who is in the least familiar with the external appearance of iron works, where ordinary puddling furnaces are in operation, knows that flame and smoke in large quantities are to be seen issuing from the chimneys attached to them. That a

great deal more fuel is being burnt than can be necessary to produce the heat actually taken up by the metal under treatment, is evident at first sight.

All, however, are not prepared for the startling fact, that whereas there is as much heating power resident in a pound of average coal as is utilized in producing seventeen pounds of puddled bar, there are very few furnaces whence more than one pound is brought out per pound of coal.

Let us examine for a moment the way in which an ordinary puddling furnace is heated. The burning coal upon the grate is supplied with atmospheric air, which forces its way among it, in endeavouring to supply the partial vacuum in the chimney. This air may be considered to enter at an average temperature of 50°F. If the interior of the chimney be examined through an aperture, situated, say, half-way up, we find that a full red or even white heat is usually maintained.

We have recently been given to understand that all our notions of high temperatures, derived from experiments with the copper-heater pyrometer, are exaggerated. The specific heat of copper and other metals has been assumed to be constant at all temperatures, whereas this is now disputed. The writer has not as yet experimented with Mr. Siemens's electrical pyrometer in its present ingenious form, and, therefore, any records of temperatures above 600°F., given in this paper, will be as taken by copper heaters, and of course subject to such modifications as that method may be proved liable.

The water pyrometer was applied in the following manner to ascertain the heat within a chimney. The heater was carefully weighed, relatively to one kept as a standard. A piece of $1\frac{1}{4}$ inch iron tube, about 3 feet long, was fitted with a wooden plug, easily removable, at one end, and the heater was placed about 2 inches within the other. The tube was then inserted so as to reach the centre of the chimney, and the opening in the latter carefully plastered up. By removing the wooden plug at the outer end, the gradual heating of the inner end of the tube could be watched, and also the subsequent attainment of the same temperature by the copper-heater.

By replacing the plug the direct oxidizing action of the air upon the copper was prevented. The cylindrical form of the tube enables

it to carry its own weight when heated even up to whiteness, and, encircling the heater, it protects it from cooling during removal, until immersion is effected. The weight having been again taken, the record was augmented in proportion to the average loss.

The mean of seven observations, where the furnace was an ordinary one, working 7 heat refined iron, and made at intervals throughout a heat, from melting to balling, showed the products of combustion to be passing off at a temperature of 2,033°F.

If we suppose 30 cwt. of coal to be consumed per shift of 12 hours, and that half the carbon therein contained is burnt into carbonic acid, and half into carbonic oxide; and if we suppose that only so much air passes through as is actually necessary to support such combustion, we shall find that about 12 tons of gases escape per shift, after having been raised from 50° to 2,033°F., by expenditure of fuel.

There is no reason to suppose that the operation of puddling can be carried on to advantage with a less intense heat than is customary, and, therefore, we are driven to consider the question whether the vast amount thereof which is shown to be wasted cannot be abstracted from the products of combustion, at all events partially, after these have passed the hearth, and before they finally escape. If this can be done, and if the heat so abstracted, can be utilized to raise the temperature of those elements, which are about to enter into combustion, it is manifest a saving of fuel must result.

Diagram 1 contains a longitudinal and a transverse section, and diagram 2 two vertical sections, and a sectional plan of an improved furnace, designed to economise coal on the principle indicated. It has been called the "Newport Furnace," from the Newport Rolling Mills, Middlesbrough, where it originated and has been developed. In general appearance it is not greatly different from an ordinary furnace. There is the fire-grate, the operating hearth, and the neck as usual. Above the neck, however, the chimney is enlarged into a chamber, divided into two compartments by a vertical cross wall reaching nearly to the top. One compartment is fitted with a damper capable of barring the passage, and the other contains a stove pipe of peculiar construction. The dividing wall is perforated by two apertures, one on either side of the stove pipe, and close to the base thereof. The chamber is surmounted by an iron-cased chimney, carried upon girders, pillars, and standards in such a

manner as to be altogether independent of the brickwork for support. When the damper is open, the products of combustion pass by way of the compartment in which it is fixed, preferring the shorter route to the chimney. When it is closed, they are forced to pass through the two apertures on either side of the stove pipe, which they heat, as well as the stove box on which it stands, and so to the chimney.

The stove pipe is rectangular in section, and contains five cross diaphragms, extending nearly to the top, which terminates semi-cylindrically. It is planed at the bottom, and stands on a planed projection of corresponding shape, cast upon the stove box. This latter is divided longitudinally by a diaphragm, which extends to, and corresponds exactly with, the centre diaphragm of the stove pipe. Great care is taken in making perfect this joint (an enlarged section of which is shown on diagram 4), as were any fissure left there might be an opportunity for passage from one side of the stove box to the other, without passing up and down the stove pipe. A V-shaped groove is therefore cut across the face of the centre diaphragm of each casting. When they are in position, the two grooves form a single channel, square in section. Before, however, the pipe is lowered, a copper wire, somewhat larger than enough to fill the square channel is introduced, and when the weight operates, the wire is tightly pressed into the channel, and a perfect joint results. A rectangular cast iron hoop, about 9 inches by $1\frac{1}{8}$ inch in section, loosely encircles the junction of the pipe to the box. The space between is filled with metal borings and acid, forming a rust joint. Should it be necessary to renew the stove pipe, the ring is broken, and the pipe is at once free for removal. One compartment of the stove box has an inlet, and the other an outlet nozzle. To the former is attached a conical pipe, the smaller end or throat being uppermost, and terminating in a funnel. Down this a steam jet constantly blows, as will presently be more fully explained. The outlet pipe at once enters the back of the furnace, being at that part made square in section, to fit the better into the masonry. When it passes the fire-bridge, it terminates in two channels formed in the brickwork. The one leads downwards into the ashpit, and the other leads upwards, and is continued by means of special annular bricks right across the roof. The special bricks have each a small tuyere-shaped aperture,

pointing downwards into the furnace, and a large one upwards, which is provided with a hollowed cast iron plug. By removing the plugs the tuyeres can be examined. Where the cast iron square-sectioned pipe terminates, a valve is attached, whereby communication with the tuyere bricks can be controlled or cut off. The ashpit is provided with doors in four sections, but which are not required to be very closely fitted.

Steam from the nearest steam-main, as high in pressure, and as dry as possible, is made to issue constantly through the brass nozzle at the top of the funnel pipe. Dryness is of more importance even than intensity of pressure. It has been found quite fatal to conduct it a long distance through a small unprotected pipe. The steam-main, properly coated, should therefore be brought as near as possible, and provision made, by a trap or otherwise, for removing any water arising from condensation. The orifice of the jet nozzle is $\frac{1}{8}$ inch, but in certain cases it may be less. The chief obstacle to the use of very small jets is their liability to become stopped up, owing to the presence of small pieces of solid matter brought by the steam. Where the joints of the mains are made with India-rubber weazes, the latter are frequently to be found more or less squeezed into the interior, and the passing steam cuts off and carries forward minute particles. If a straining box, containing a diaphragm of fine wire gauze, and capable of periodic examination, be inserted as shown, immediately above the steam jet, then the orifice may be made extremely small.

Pouring down the conical pipe, and spreading out as it goes, the steam seizes upon the air in immediate contact with it, and forces it into the pipe. The jet operates best if the orifice is about 3 inches above the throat. This is made $2\frac{1}{2}$ inches in diameter, the jet at that part having become widened out to 1 inch in diameter. An annular space is left, $\frac{3}{4}$ inch in breadth, through which the air is drawn in. The suction at the throat is sufficient to sustain a column of water $3\frac{1}{4}$ inches high, with a pressure of steam of 40 lbs. above the atmosphere. Sometimes, under specially favourable circumstances, a vacuum sufficient to sustain a column 5 to 6 inches high has been obtained. The velocity with which 40 lb. steam issues into the atmosphere is about 1,728 feet per second. The amount of water which must be evaporated to support an $\frac{1}{8}$ inch jet, is 1·04 cubic feet, or 65 lbs. per hour, and represents a consumption

of 1 cwt. of coal for twelve hours, if a specially fired boiler is used. The velocity of air passing the annular space, and due to a suction corresponding to a column of water $3\frac{1}{4}$ inches high, is 112 feet per second, and amounts to 900·4 lbs. weight per hour. Thus we are able to arrive at an estimate of the relative weights of steam and air in the mixture as it enters the stove box. It is one of steam to $13\frac{3}{4}$ of air by weight, or if volumes are taken at atmospheric pressure, we shall find the proportion to be one of steam to $6\frac{2}{3}$ of air. This mixture of steam and air, on emerging from the stove box, has a pressure which will balance a column of water $\frac{1}{4}$ inch high. It has now become the vehicle by which some of the waste heat is abstracted from the products of combustion, and conveyed to the back of the furnace for utilization.

Professor Tyndal's researches have revealed the marvellous effects of mixing moisture with air, in increasing the capacity of the latter for the absorption and radiation of at all events the obscure heat rays of the prismatic spectrum. The stove pipe and upper surface of the stove box are maintained at a scarcely perceptible red heat. Radiation internally takes place across the spaces enclosed, and through which the moistened air is slowly passing. The object aimed at is to gather as much heat, with as little heating surface as possible, in order to reduce complication to a minimum. After passing up one side and down the other, and emerging into the outlet pipe, the blast is usually about 550°F. The inlet pipes are carefully coated with a carbonaceous non-conducting material, but the outlet pipes require an incombustible coating.

All through the back of the furnace the blast increases, or at least maintains its heat until it reaches the tuyeres or ash-pit. There it has still sufficient pressure left to blow forcibly away any dust or light material which may be thrown across its place of exit.

Before passing through the fuel, it acquires additional heat from the downward radiation of the fire, and from contact with the fire-bars. These are found to last longer in the improved than in the ordinary furnace, and, of course, any heat taken from them must be acquired by the blast. Although the ash-pit doors are intended to be kept closed, and this ought to be impressed upon the attendants, yet it has not been found that the consumption of fuel has been materially affected by neglect of this duty. It is certain that

the blast, on arriving at the grate, is superior in pressure to the external air, and, therefore, it probably excludes it from opportunity to approach the grate.

It is not improbable that a portion of the steam in the blast may become decomposed. A common method of making hydrogen gas is to pass steam through a red-hot tube containing iron turnings, also red hot. These seize upon the oxygen of the steam, forming oxide of iron, and the hydrogen is set free. This is exactly what the steam in the blast is subjected to when in the stove-pipe, and also when at the grate-bars. The only question is whether those surfaces are ordinarily heated sufficiently to effect the decomposition. If they are, we should expect to find rapid oxidation. Some oxidation does undoubtedly take place at both places, but present experience does not warrant the belief that it is very rapid.

But the steam with which the blast is permeated probably does good in another way, viz., that in which it has been shown to benefit in gas producers. On reaching the carbon upon the grate, it becomes decomposed into its constituents—oxygen and hydrogen—absorbing heat in the act. The oxygen seized upon by the incandescent carbon passes forward as carbonic oxide. This gives out heat on receiving a fresh supply of oxygen at the fire-bridge from the tuyeres. The liberated hydrogen passes forward, also ready on finding oxygen to recombine and give out the heat where it is wanted, which it took away from just above the grate, where it was not wanted.

The proportion of air admitted through the tuyere bricks, above the fuel, must be carefully regulated, so as not to exceed what is necessary to complete the combustion, otherwise it will tend to oxidize the charge. The damper in the stove chamber need never be completely withdrawn, unless from any cause the steam jet be inoperative. Then it would become necessary, or there might be danger of burning the stove pipe.

The average of four experiments made upon a Newport furnace to ascertain the heat at which the products of combustion pass off after leaving the stove chamber gave 1,577°F. The observations were made the same day, and under precisely similar circumstances in all other respects as those from which the temperature within the chimney of an ordinary furnace was found to be 2,033°F. The waste gases of the one escape 456° cooler than those of the other.

No flame is ever visible at the top of the chimney of the improved furnace, even at night. The smoke also seems to be lessened, both in duration and intensity. Throughout the course of a heat, a chimney was specially watched, in order that an accurate judgment might be formed on this question. Smoke was never seen to continue more than one minute after firing, and even during that period objects intercepted by the smoke were clearly distinguishable. The dense black cloud which proceeds from the chimney of an ordinary furnace, especially when the attendant fires with his damper down, was never visible.

When we bear in mind the saving of fuel effected in smelting furnaces, owing to the utilization of the waste gases by causing them to heat the blast, it can be no marvel that a similar saving should result from the application of a like principle to puddling furnaces. We may expect to save, because the heat of, let us suppose, 2,500°F., which we require at the fire-bridge and over the hearth, and there only, has been contributed to, without any new expenditure of fuel, in the following ways, viz.:—

1st. By supplying the air for supporting combustion at 550° instead of 50°.

2nd. By the possible admixture with that air of some free hydrogen, owing to decomposition in the stove-pipe and box and at the grate bars.

3rd. By the transference of some heat from the grate to the fire-bridge, by the action of the incandescent fuel upon the steam.

What the saving of fuel actually is may be gathered from the following records :—The quantity of iron used in producing a ton of puddle bars, is also appended, as although saving of fuel is highly desirable, it must evidently not be at the expense of an increased consumption of the more costly material. The furnace which has yielded these results is one which is exactly represented by the model exhibited, when surmounted by the boiler. There is no material difference in any other respect between it and that illustrated in diagrams 1 and 2.

The furnace was employed upon 7-heat refined Cleveland iron. The coal was mostly Pease's West, costing at the time 6s. 4d. per ton delivered. That used for lighting up, and amounting to 9 cwt. 1 qr. 0 lbs., weekly, is included. The records embrace eight weeks, viz., almost the whole of June and July, 1871.

Occasionally heats were lost. The puddlers were not aware that any unusual accounts were being kept.

The average coal consumption under these circumstances was 12 cwt. 3 qrs. 6½ lbs. per ton of puddled bar, weighed after rolling.

The average consumption of refined iron, was 20 cwt. 2 qrs. 24 lbs., or, in other words, the puddled bars weighed 96½ per cent. of the iron charged.

The fettling used was made in a tap furnace from various cinders and scraps, and similar materials produced on the premises, and contained no hematite or other costly native ores.

The boiler, which is no essential part of the furnace, evaporated during the same period an average of 10·1 cubic feet per hour, from about 180°F. into 50 lb. steam, as registered by a Siemens water meter inserted in the feed pipe. A similar boiler attached to an ordinary puddling furnace evaporates 20·4 cubic feet per hour. This again gives an idea of the proportion of heat intercepted by the stove pipe.

As the addition of the boiler doubles the cost of the furnace, it is a question whether it is not wiser to use either one or the other method of intercepting the waste heat, but not both.

In working six-heat iron, an increase in the consumption of coal per ton of puddled bars is, of course, to be expected, because the same, or, perhaps, rather a greater heat must be maintained over the same time, with a produce diminished in the ratio of 6 to 7. The writer has accurate records of two furnaces over five weeks, whilst working six-heat all grey iron. They were not fitted with the more recent improvements, and the coal was only of ordinary puddling quality. The average consumption was 14 cwt. 3 qrs. 25 lbs., or very nearly 15 cwt. per ton of puddled bar.

Of furnaces working upon the Newport principle, but incomplete and imperfect in many respects, there are twenty-four, besides five with all recent improvements, at the Newport Works.

Separate accounts were kept for ten months in regard to the former, with the following result:—

Coal used per ton of puddled bar, including lighting up and firing, during all stoppages:— ... ... 16 cwt., 1 qr., 27 lbs.

Iron used ... ... 21 „ 1 „ 21 „

The ordinary furnaces at the Newport Works, use an average of 24 cwt. 2 qrs. 0 lbs. of the same coal, and $3\frac{1}{10}$ per cent. more pig

or plate iron, to produce the same weight of puddled bar. The fettling is the same in either case.

The beneficial effect of the improved furnace in reducing the waste of iron as well as of fuel, becomes comprehensible when we remember the agent by which waste is produced, viz., free oxygen sweeping over the hearth, and attacking the metal. This free oxygen is present, owing to the considerable excess of air, which is often allowed to penetrate to the top side of the fuel, in order that combustion of the distilled gases may there go on—in other words, that flame may fill the furnace.

It is quite to be expected that when the air for supporting combustion is heated, the same flame can be kept up as required with a less excess than when cold air is supplied. That this is the true explanation, is confirmed by the fact that the whole benefit in saving waste of iron, disappears, and the evil is even exaggerated, if the quantity of blast going by way of the tuyere bricks is allowed to become excessive.

It has been stated that the quantity of air forced into the stove box by the steam jet, is, under certain circumstances, 900·4 lbs. per hour, or nearly 5 tons per shift of twelve hours. It will be interesting to enquire, how much is actually required by the fuel on the grate, to produce the observed effects, and then to compare the two.

During the eight weeks' experiment previously referred to, with the furnace represented by the model, an average of about 20 cwt. of coal per shift was used. The coal contained by weight about 85 per cent. of carbon, 5 per cent. of hydrogen, 5 per cent. of oxygen and nitrogen, 5 per cent. of ashes.

The first two ingredients are alone combustible, but we do not obtain the full benefit even of them.

The ashes falling from the grate of a puddling furnace weigh usually not less than 25 per cent. of the weight of coal charged. They have not unfrequently been known to amount to 36 per cent. Let us take them at the lower figure. They will include the 5 per cent of ash, and 20 per cent of the carbon. Thus all we really burn is 65 per cent of carbon and 5 per cent of hydrogen.

If we assume that half the carbon is burnt into carbonic acid, and half into carbonic oxide, and that the whole of the hydrogen is burnt into steam, we shall find that the air required for 20 cwt. of coal per shift would be about $6\frac{3}{4}$ tons.

Our barest requirements seem to be $6\frac{3}{4}$ tons, and we cannot find that quite 5 tons are supplied. The result at first seems perplexing. It is of course quite easy to increase the size of both jet and throat, and so the quantity of air induced ; but the furnace works perfectly well without, and evinces no sign whatever of a need of more air.

It is probable that the apparent deficiency is made up from other sources. Air is introduced with the fuel during stoking, and perhaps filters in at the hopper, and through minute crevices in the brick-work. All coals are believed to contain some oxygen in combination. Lastly, the heat from the grate radiates downwards, and doubtless reaches the water in the ash pit, already made hot by the falling ashes.

The vapour rising from this water enables the air contiguous to it to absorb the heat rays, and so raised in temperature it is ready to make up any deficiency in quantity of blast.

The cost of a puddling furnace erected *de novo*, as illustrated in diagrams 1 and 2, is in the Cleveland district about £170. The cost of an ordinary puddling furnace, in the same locality, is about £120. The maintenance in repair may be considered about the same in either case relatively to first cost.

Diagram 3 contains a longitudinal and a transverse section, and diagram 4 contains a sectional plan, and a section through the stove chamber, of a double furnace arranged upon the Newport plan, and fitted with Mr. James Whitham's double puddling machine.

Double furnaces of large capacity with machines attached have been for some years in successful operation at the Perseverance Iron Works, Leeds. Upon the diagrams they are arranged in pairs, and a portion of the second furnace consequently appears.

Mr. Whitham's practice is understood to be to charge 15 cwt. of pig iron per heat, and to obtain five heats per shift. His consumption of ordinary puddling coal is stated to average 14 cwt. per ton of puddled bar, and his consumption of pig iron 75 cwt. to produce 72, or 20 cwt. 3 qrs. 9 lbs. per ton. These heavy charges could not, of course, be worked without the machine. It is contended that a combination of the Newport with the Whitham furnace, as illustrated, ought to modify, still more favourably, the already favourable results produced by each separately. The two plans are perfectly distinct, and there seems to be no reason why the advantages of each should not be obtained without damage to the other. The

Newport furnace seeks to economise, by producing the necessary heat with a minimum expenditure of coal per square foot of grate. The Whitham furnace seeks to make each square foot of grate suffice for operating upon as much iron as possible.

If all our data are correct, and all our arguments are sound, we may expect such a combined furnace, under fair management, to arrive at a consumption of only 10 cwt. of coal per ton of puddled bar, and perhaps a somewhat reduced waste of iron. Both elements of the combination have been separately in operation for some years, and, therefore, both may be considered to have passed the experimental stage.

But certain additional advantages might be obtained with such a furnace. If, instead of five heats per shift, obtained by hard-worked men in something under eleven hours, four heats were expected from fresher hands in eight hours, then three shifts per twenty-four hours might become the rule. The full production of such a furnace, so handled, would amount to 65 heats, or 45 tons 10 cwts. of puddled bars per week. This is at least three times the production of the best ordinary single furnace. The advantage of the eight-hour, over twelve-hour shifts, would be represented by an increased production of 20 per cent.

The cost of adaptation of the Newport principle to a Whitham furnace is estimated at about £120.

Besides the furnaces already mentioned, there are several in operation at other works. The Blaenavon Iron Company have had sixteen since the commencement of 1870. Messrs. Jones Brothers, of Middlesbrough, have recently erected eight. In neither of these cases have the latest improvements been added; still the report given by the owners is very good. Mr. John Paton, of Blaenavon, states that the consumption of slack coal there averages 14 cwts., 2 qrs., 10 lbs. per ton of puddled bar. The following is a quotation from a letter recently received from him:—"Our Newport furnaces continue to give satisfaction. We never had a complaint from the men as to their working, and have always found they were as readily taken to, when only slack was allowed, as the other furnaces which are supplied with coal. The yield of iron is satisfactory. For coal yield, see our previous report."

Mr. J. A. Jones, of Messrs. Jones Brothers, reports the result of an experiment, of a month's duration, made by him, to be as follows,

viz.:—Average coal per ton of puddle bars, $16\frac{1}{4}$ cwts.; average coal used by his ordinary furnaces, 24 cwts.; average consumption of pig iron, $\frac{1}{4}$ cwt. per ton, or $1\frac{1}{4}$ per cent. better in the Newport than in the ordinary furnaces. In both cases similar grey forge pig iron and similar fettling was used, and six heats per shift worked. His grate bars lasted one-third longer in the Newport than in the other furnaces.

At the West Cumberland Hematite Iron Co.'s Works at Workington, two double furnaces were altered at the commencement of 1871, to the most recent model. These furnaces are not so large as Mr Whitham's, and have no machines attached.

Mr. Wm. Fletcher's most recent report is as follows:—"Since my last letter we have very carefully noted the working of our two double furnaces, upon the Newport plan, and as the results have been better than those which I then gave you, it is only fair that I should let you know of them. During the week ending September 9th, we used all grey pig (a mixture of hematite and Cleveland) in 12 cwt. heats, when the iron yield was 20 cwts. 2 qrs. 15 lbs. per ton of puddled bar, and that of coal 14 cwts. 1 qr. 9 lbs."

Had these furnaces been increased to the dimensions of Mr. Witham's, and his machine superadded, the produce would have been increased 25 per cent., with in all probability no increase of fuel.

The series of experiments to which the Newport furnace owes its origin, were commenced and carried on for some time for the proprietors of Newport Rolling Mills, by Mr. J. A. Jones, of Middlesbrough, then works manager to the firm. Valuable suggestions have been made at different times, by Mr. Jno. Gjers, and Mr. R. Howson, of Middlesbrough, and Mr. B. Ford, of Stockton. Most of the earlier arrangements in detail have been found imperfect, and have been abandoned, though the leading principle, viz., the use of a mixture of air and steam, as the vehicle by which the waste heat is restored to the grate, remains the same. The later experiments, and the development of the furnace into its present form, have been the work of the writer of this paper.

The President was sure they had listened to the paper with a very great deal of pleasure. The thoroughly practical way in which the matter had been described would have enabled all to form a correct opinion of the improvements which had been introduced in the Newport Puddling Furnace. He, therefore, proposed a cordial vote of thanks to Mr. Head for his paper.

Mr. Edward Williams said that he fully concurred in what had been said by the chairman, that the thanks of the meeting were due to Mr. Head for his very clear paper on the improved puddling furnace, but he could not help thinking that he stood pretty much in the position of a person endeavouring to improve mail coaches after the introduction of railway trains. It seemed to him that the revolving vessel either was a success, or so near one, that it must soon be made to answer, and that they were not likely very much longer to travel by the mail coach of the old puddling furnace. He hoped they would get rid of the existing furnace altogether, and, by means of the revolving vessel, do away with much hard manual labour. They had heard gentlemen talk of the heat in puddling, blast, and other furnaces at from eleven hundred to twenty-one hundred degrees Fahrenheit, and he desired to be informed how such heats were measured, because he had failed to ascertain, with anything like accuracy, heats over about eight hundred degrees. He had taken the best pyrometers that he could get, including Mr. Siemens's, but it unfortunately happened that two or three, used under the same circumstances, did not register alike. Now, it seemed to him to be dangerous to assume that they knew exactly the heat of a chimney, or a blast furnace, or anything else, when the figures, shown by imperfect measuring instruments, gave results that might be very far from correct.

Sir John G. N. Alleyne said they should not let Mr. Head go away from the meeting, telling him that he was attempting to improve a mail coach instead of accepting the railway train. Mr. Head was trying to economise fuel, and whether he was right or wrong they ought to endeavour to remove any such impression as that to which he had alluded. Mr. Bell sometimes told them a great deal about the constituents of fuel, and the combustion of the various gases it contained, and he wished to ask that gentleman to answer the questions raised upon the subject before the meeting. He hoped they would not allow Mr. Head to go back to Middlesbrough

with the idea that they thought he was trying to drive a mail coach in front of an express train. He thought he was following Mr. Siemens's plan to some extent, and in doing so he was trying to economise the waste heat, which under present circumstances it was impossible to utilize. In puddling, it was necessary to melt the iron, and Mr. Head suggested the saving of all the waste that generally went up the chimney. His method of doing so was by heating the air previous to combustion. Some people, himself among them, used it in getting up steam for the engines. Mr. Siemens was doing the same thing by heating his gas and air. He thought they ought to ask Mr. Bell to explain all about carbonic acid and carbonic oxide. He confessed he was unable to comprehend the subject very clearly, but he generally went away from the Institute meetings knowing something more about the matters discussed. He believed Mr. Head was in the right way in what he was doing, and he should not like him to leave the meeting with any other opinion.

Mr. I. Lowthian Bell said Sir John had told them that he always went away from the meetings of the Institute feeling that he had learned a little more than he knew before. He (Mr. Bell) generally went away impressed with the fact that he had a great deal more to learn than he knew before. He was afraid he could not satisfy Sir John on the questions he had addressed to him, but he quite agreed with what fell from him upon the subject of the paper itself, and he thought it was unnecessary for Mr. Head to speak in the depreciatory way he did about his furnace, because, although it was not an invention for dealing in a new way with pig iron in its manufacture, it was directed to the economising of fuel in that operation. Now, if the invention itself were of that nature, he could see no reason why it was not quite as applicable to a Danks's furnace, as to an ordinary puddling furnace. Therefore, he trusted that Mr. Head would not be discouraged, and consider himself eclipsed by the sun, which, instead of rising in the east in the ordinary manner, had on that occasion appeared in the west. He agreed, too, with Mr. Williams about the easy way in which it was customary to speak of high temperatures. He had had occasion, in his investigations on the blast furnace itself, to endeavour to ascertain, as nearly as he could, temperatures of a very elevated character, and the difficulty he had

experienced had been such that he was unable to boast of any great success in that important subject. The last attempt he had made was by taking one of the most infusible materials known—that of an alloy of platinum and iridium. This he exposed to a current of heated slag, as it flowed from the blast furnace, but the platinum alloy, although not fusible at that temperature, was so softened by being exposed to such a heat, that it was wasted by the current of the slag itself. Now, the members of the trade in the North—who knew Mr. Head so well—were quite certain that he stated nothing in that paper which he did not believe to be strictly true, and he was quite willing to grant the most ready assent to the saving of fuel, as stated by him. The only thing to which he took exception was, that although that saving might have been realised, the causes for it which he assigned could not be correct, for he did not believe it possible to introduce steam or water in any shape whatever into a fire, and produce by that means the effects which he had described.

Mr. Head pointed out that a certain action might be obtained by transferring, as it were, combustion from one locality of the fire-place to another—that having decomposed water in one part of the fire, he would thereby obtain a calorific effect in another part, by the combustion of the hydrogen evolved.

Mr Bell, continuing, said that Mr. Head had not favoured them with any information as to the means employed for ascertaining that, and from the known action of hydrogen or carbonic acid, he would doubt the correctness of the assumption.

Mr. W. Whitwell would like to add his testimony to that of previous speakers as to the interest attaching to the paper read by Mr. Head. He would also like to add his appreciation of the extreme industry with which Mr. Head had, for a period of years, applied himself to the perfecting of a series of experiments, which had led at last to the results set before them in his paper. Having himself been connected for some years with experiments, in an adjoining works, in connection with a different system for economising fuel—experiments which had not by any means proved so successful as Mr. Head's plan—he would still further congratulate him upon his success. Then with regard to the comparison drawn by Mr. Williams between the stage coach and the railway train, he ventured to submit that that was not quite *àpropos*, because they must

remember that for the last few years the bulk of those engaged in the manufacture of iron had been using from 22 cwts. to 23 cwts. of fuel per ton of puddled iron, whilst Mr. Head told them that he had obtained the same, if not better, results, as far as the waste of iron was concerned, by a consumption of something like 14 cwts. 3 qrs. 25 lbs., or, on an experiment extending over ten months, with ten furnaces, 16 cwts. 1 qr. 17 lbs. per ton of puddled iron. They would agree with him that this was a most admirable result, and, comparing it with the ordinary work obtained from twenty of the other kind of furnaces for the same period, showed a saving of from 6 to 7 cwt. of coal, or two shillings per ton on the puddled iron produced, which, to the practical ironmaker, was a matter of extreme importance. The experiments to which he had previously referred, were tried at the works of Messrs. Whitwell & Co., in connection with Mr. Wilson's furnace, as improved by his (the speaker's) brother, and although they did obtain in the experiments as good a result as Mr. Head had shown in his figures, viz., from 14 to 16 cwts. of coal, yet in practice that result was not maintained, and the waste which they experienced, and which they could not prevent, owing to the carelessness of the operatives, or from some other cause, clearly proved that Mr. Head's plan was much the better one, and therefore he congratulated him most cordially upon his success. Whether Mr. Head was wrong as to the decomposition of the steam, as maintained by Mr. Bell, or not, he had told them very simply the results he had obtained, and the members must thank him accordingly.

Mr. Plum would like to ask Mr. Head if his system had been applied to a ball furnace, and if so, with what result?

Mr. Jeremiah Head proposed to answer the various remarks which had been made, in rotation. Firstly, with regard to what fell from Mr. Williams, to the effect that he who now occupied himself in trying to improve the process of puddling by manual labour was like one seeking to perfect travelling by stage coaches, after the advent of railways, he begged to say he fully concurred in that sentiment, and indeed, he tried to express it as clearly as he could in his introductory remarks. Unfortunately, however, Mr. Williams was not present at first, and so he had not heard what had been said. He ventured, therefore, to repeat that he had not pretended to deal with the operation of puddling, whether by

hand or otherwise in any shape or form; but had simply sought to show how to save fuel by utilizing the waste heat. There was no reason why the principle of the Newport furnace should not be as applicable to ball, heating, tap, or even rotating furnaces, as to hand puddling ones. As to the accuracy of his measurements of temperatures, he fully expected some would be sceptical, and, therefore, he had described somewhat elaborately the method he adopted; but this also was unfortunately before the arrival of Mr. Williams. The British Association made a grant last year to a committee of the Royal Society, for the purpose of experimenting with, and reporting upon, the electrical pyrometer, most recently invented by Mr. Siemens, and no doubt that report would shortly be forthcoming, and would be of the greatest interest. If it turned out that an instrument had been found by which high temperatures could be accurately measured, it would be quite an event in the history of metallurgy. In reply to Mr. Bell's remarks, he did not propose for one moment to enter into a discussion upon a chemical question with so high an authority. But they might rely, as Mr. Bell had kindly admitted, upon the trustworthiness of his experiments. He had exactly recorded what he observed, and if the theories he had advanced to account for the phenomena were pronounced fallacious, he could only say, that being always anxious to learn, he would like to know the true causes of such remarkable results. He might add that he could not claim originality in his attempt to solve the question, as what he had said had been gleaned mainly from the writings of Tyndal, Roscoe, and Siemens, and he had Mr. Crossley's approval of all he said. He had only further to state, in answer to Mr. Plum, that he had not yet applied the Newport principle to any but puddling furnaces.

The President said the next portion of the business would be the reading of a further report from the Puddling Committee.

The following report was then read:—

"In the Report presented to the last Annual Meeting, the Puddling Committee stated that they recommended the appointment of two gentlemen for the purpose of visiting the various ironworks in Great Britain, where improved arrangements for puddling had been introduced. Immediately upon their re-election, the Committee proceeded to carry out this arrangement. They engaged the services of Mr. Bodmer to report upon the mechanical features of any apparatus

that had been designed for the purpose of improving the puddling process, and through the kindness of Messrs. Hopkins, Gilkes, & Co., of the Tees-side Iron Works, Middlesbrough, they were able to secure those of Mr. Richard Lester, to carry on the practical part of the enquiry. These gentlemen have spent about 80 days in carrying out the investigation entrusted to them. It is not necessary to enter into minute details of their proceedings, as their reports upon all the more important improvements that have been tried in this country of late years have recently been published in the JOURNAL OF THE IRON AND STEEL INSTITUTE. The arrival of Mr. Danks in this country, and his statement to the effect that his machine was then in successful operation in America, tended to make the enquiry of the English Commissioners of less value. They investigated the merits of the rotary puddling apparatus as far as they could be made out from the materials at their disposal, and from the first they spoke most favourably of Mr. Danks's improvements. It was felt that the statements of Mr. Danks ought to form the subject of an early communication to the general body of members, and arrangements were accordingly made, by which the merits of the new apparatus might be described and investigated at the provincial meeting, to be held in Dudley, in the succeeding August. The English Commissioners, therefore, handed over their report to the Puddling Committee. They then proceeded to complete their enquiry. They were in several instances called upon to report upon processes and arrangements which, at the time of their visit, were in an early and experimental stage, but which have been subsequently improved to a considerable extent. Special papers on some of these subjects will be submitted to the present meeting. Altogether the English Commissioners collected for the Committee particulars of nearly everything of importance that has been done during the last few years, with the view of improving the puddling process. This information is now in the possession of the Committee, and will doubtless be of much value, both in a practical and historical sense.

"When the Puddling Committee met at Dudley, and considered the statements contained in Mr. Danks's paper, they felt that it would be advisable to appoint a qualified commission for the purpose of making a thorough investigation of the operation of Danks's Puddling Machine in America. They suggested this course to the General Meeting at Dudley, and their recommendations being

approved, they proceeded to carry out this arrangement as speedily as possible. They requested the Dowlais Iron Company to allow Mr. Snelus to report on the scientific facts, and the Company very liberally and cordially acceded to the wishes of the Committee. They asked Mr. J. A. Jones, of the Ayrton Rolling Mills, Middlesbrough, to act on the Commission, and he kindly consented to serve. The Committee also desired the trade in South Staffordshire to nominate a third member of the Commission, and Mr. John Lester, of Wolverhampton, was accordingly appointed. The Committee held several meetings to arrange the details of the enquiry. They provided forty tons of pig iron and a quantity of the fettling material available in this country; and early in October the Commissioners left Liverpool for America, accompanied by Mr. Danks. The Committee drew up detailed instructions for the guidance of the Commissioners, and these have been rigidly and minutely acted upon. The Commissioners were allowed the fullest opportunities of carrying out their experiments at the Cincinnati Iron Works; they also visited every other place in America where Danks's apparatus was then at work, and about the middle of December they sent off from Washington their general report. The Committee having considered this document, and being aware that the members felt a deep interest in the American enquiry, decided to publish the report immediately, and the details are therefore well known. They have, however, requested each Commissioner to submit to this meeting a supplementary report, dealing with various matters that it was impracticable to introduce in the joint communication.

"The Committee finding themselves pledged to an expensive enquiry which was likely to be of great advantage to the trade, and feeling that it would be unfair to burden the resources of such a young Institution with the cost of this investigation, decided to make a general appeal to the iron manufacturers of the country for special funds with which to defray the expenses of the enquiries upon mechanical puddling. This appeal was very liberally responded to, but as the total cost will turn out to be much greater than was originally anticipated, the funds already subscribed will not be sufficient to meet the total outlay.

"The Committee learn with much satisfaction that the English Commissioners were received in a most courteous and hospitable

manner throughout the States, and they desire to record their obligations to the American iron trade for the facilities they afforded the Commission for pursuing their enquiry; and also to a number of gentlemen who in various ways contributed to promote the success of the investigations.

"Whilst the Commission was in America, Messrs. Hopkins, Gilkes, and Co., of Middlesbrough, proceeded with the erection of a revolving puddling furnace on Mr. Danks's system. This was completed about the middle of February, and as the firm invited the Puddling Committee to see it in operation, a meeting was held at Middlesbrough at the end of last month. The experimental furnace was found to do its work in a highly satisfactory manner, and fully confirmed the statements that had been made by the Commissioners. It was not possible to do very much, except to see the working of the machine, and to test the quality of the finished iron produced. In all these respects the experimental workings were eminently successful.

"The Committee also visited the West Hartlepool Iron Works, in order to see Mr. Spencer's machine in operation. They saw two heats of about 10 cwt. each puddled, in a comparatively short time, the iron produced being of good quality, and working well under the hammer. In the last heat the iron was brought out in two large and well shaped balls. The machine of Mr. Spencer has been described in the reports of Messrs. Bodmer and Lester, but as it appears to have undergone several important improvements, subsequent to that description, the Committee requested Mr. Spencer to make a short communication to this meeting upon his furnace, as it is now in operation.

"Messrs. Howson and Thomas also showed the Committee a revolving puddling machine, recently erected by them for experimental purposes, at the Newport Iron Works, Middlesbrough. The Committee saw two heats worked in this apparatus, and though many of the arrangements were incomplete, the iron was puddled successfully; but as the apparatus was not attached to a forge, the material produced could not be examined. The Committee have requested Messrs. Howson and Thomas also to make a communication on this subject to the Institute at the present meeting.

"The Committee do not feel called upon to record their opinions

as to the relative merits of the various machines for puddling iron that have come under their notice. They have endeavoured to collect as much information about each as was possible, and this they have communicated, or have arranged to communicate to the Members, who will thus be in a position to make their own deductions from the information now available. The Committee will continue to give their attention to this important question, and at a future meeting they will report the results of their further investigations."

Mr. Menelaus proposed the adoption of the report, and said to do so was to him a very peculiar pleasure, which would be easily understood when he said that the report promised—and, he thought, promised fairly—that, bye and bye, they would get rid of hand puddling. The Puddling Committee had not given a very decided opinion yet as to the merits of the various rotary puddling machines, and that for very obvious reasons. They had not had an opportunity of investigating fully and fairly the merits of the Danks machine, as erected by Mr. Hopkins, or of examining thoroughly the rival apparatus—and a very clever and ingenious machine it was—introduced by his friend Mr. Spencer. They would, therefore, see that the Puddling Committee had withheld—and he thought wisely—a very decided opinion as to the merits of the rotary puddling machines until they had (as they would have shortly) a full opportunity of investigating the merits of the Danks Rotary Machine, and also those of other machines which were being brought out. They all knew that he had paid considerable attention to the subject, and for himself he might say frankly that he accepted the report of the American Commission fully, and considered that the question of puddling in rotary vessels was what might be called an accomplished fact. He had no hesitation in saying that, first, from his own experience, and next, from the facts detailed in the report of the American Commission. From what he had seen of the Danks machine, at Middlesbrough, of Mr. Spencer's machine, at West Hartlepool, and of others—probably of less merit, but which the inventors had had less time to perfect—he heartily congratulated Mr. Danks on the success which had attended his attempts to improve the rotary puddling machine, and he said there—and he wished him to accept the compliment as he intended it—that all his (Mr. Danks's) modifications were exceedingly ingenious, exceed-

ingly effective, and that they answered the end for which they were intended. His improvements were exceedingly clever, and did him the very greatest credit. He would also further say that he thought it redounded very much to the honour of Mr. Danks, that after all he had said at Dudley (and he was there speaking as an inventor in favour of his own child), he repeated that all Mr. Danks said at Dudley had been fully verified by the investigations of the American Commission. He thought it was no small compliment to Mr. Danks to be able to say so. He would next come to Mr. Spencer's machine. He considered it was very ingenious, but he thought he was complicating the machine in striving to divide the heat. He saw Mr. Spencer before him, and hoped he would accept his advice in the spirit in which it was given. He thought he was, as he said, complicating the machine, and increasing the difficulty of dealing with mechanical puddling, by trying to get the heat out in two or three balls. He believed it would be far better to accept, and to accept at once, the difficulty of dealing with a large mass of iron, rather than with a greater, viz., that of bringing out the heat in separate balls, which could be worked under the hammer or the squeezers. He had no doubt (having paid some attention to the question) that even 10 cwt. balls might be readily worked by special machinery, and, he thought, less inventive skill would be required to adapt machinery for that purpose, than was necessary for the very complicated process of dividing the heat inside the vessels. If they went in for dividing the heat, it would increase unnecessarily the size of the vessel, which had to be of a complicated form, and other difficulties would have to be contended with which, he thought, were very great indeed; and, if he might be allowed to give advice to his young friend, he would say "go in for what Mr. Danks is doing, and for what everyone has done up to this time, and simply accept the difficulty of dealing with a great mass of iron—say 10 cwt.—as a lesser difficulty than trying to divide the heat." As he said before, the Puddling Committee had not had a full and fair opportunity of investigating the merits of the several rotary vessels, and of deciding, among the various plans, as to which was the best. But he hoped, before their meeting in Glasgow, that they would have had an opportunity of doing so, and then, he believed, the Puddling Committee would speak out upon the subject with great frankness—a frankness which they were not

able to exercise, just at that moment, for the reasons he had stated. However, he promised for himself, and for the Puddling Committee, that they would, with even increased zeal, examine this process of mechanical puddling, and, at the next general meeting, would tell the Institute their opinion of its merits. They would then, he hoped, be able to recommend what they thought to be the best method of puddling in rotary vessels, and he trusted before long they would get rid—if not altogether—almost entirely of the hard labour of hand puddling. The prospect was to him a matter of great satisfaction. He had made puddling in rotary vessels, as they all knew, a study for many years, therefore, it was a great satisfaction to him to be able to stand there and say, before a meeting of that kind, that he believed mechanical puddling was then what might be called accomplished, and that it was a success.

Mr. I. Lowthian Bell, in seconding the adoption of the report, begged leave to supplement the brief and very lucid history which Mr. Menelaus had given with regard to the introduction of mechanical puddling. He had entirely omitted (as all those who were acquainted with him knew he would do) all mention of the part he himself had taken in the development of the matter. Now, Mr. Menelaus had told them frankly how he had failed; he, for his own part, knowing Mr. Menelaus's intimate acquaintance with the manufacture of iron, could never be persuaded that the problem of mechanical puddling did not owe much to him, not only from the fact of his mind having for a long time been directed to its solution, but also from the very fact that Mr. Menelaus himself, for a considerable period, believed in, and did a great deal towards, its accomplishment.

Sir John Alleyne said, that as a member of the Puddling Committee, he himself had had an opportunity of seeing two machines at work. Mr. Danks's machine, he believed pure and simple, was put up by Mr. Hopkins, and Mr. Spencer's apparatus differed from that in some measure. But Mr. Spencer need not necessarily separate the heat into balls. He had an ordinary steam hammer for shingling, and he could shingle a large ball. Mr. Hopkins tried to shingle, and he did shingle as well as he could up to 11 cwt.; but because Mr. Spencer could separate the heat into small lumps, he did not think he should endorse Mr. Menelaus's advice and tell him to abandon it. Mr. Spencer could make small balls if he liked, and if he chose to hang his boxes centrally, all the balls would come

out like those from Mr. Danks's machine. One great feature in Mr. Spencer's machine was that his lining was put in melted. He used ordinary mill furnace cinder (which they had all employed from time immemorial), and he had succeeded in making a bottom without using any expensive materials, or putting it in like Mr. Danks did. He thought it was a machine which he should not turn away from in a hurry, and he intended to look very fully into the matter. It was simple, and the mere fact that he tumbled his four cornered boxes about in such a way as to give an end action to the charge, as well as a rotary action, thereby separating the material into several balls, was not in his opinion an objection. If he rolled it round on the axis of the cylinder, he would make the heat in the same manner as Danks, and he could not see the harm of being able, in one part of the works, to obtain small balls, and, in another part, large balls, varying in size from 10 to 17 cwt., or even a ton of iron, so long as he got in that way a ball of the size he might want. He rather looked upon that as an advantage, Then they came to Mr. Danks's movable flue; he thought it was a very great point to be able to move that flue in the handy way that could be done By that means it was only necessary to put the tongs in and draw the ball out. There, he believed, Mr. Danks had an advantage over Mr. Spencer, because Mr. Spencer had a door in the side of his furnace through which to drop the balls, and, in doing so, the lining must be injured each time. That was a point to which he wished to call the attention of the meeting, and he should advise the members to look at both machines before they decided upon either.

Mr. W. R. I. Hopkins said the chairman had just asked him, as having set to work the first machine on the Danks principle in England, to say a word or two upon the subject. It was pretty well known by the members of the Institute that, about a month ago, the firm to which he belonged had a machine ready for working, and he invited the members of the Puddling Committee to Middlesbrough to see it. A good many of them came, and he believed they had all expressed themselves satisfied with its performance. The best commentary that he could make upon the subject was that his firm were so satisfied with the result of puddling in Mr. Danks's apparatus, that they were proceeding at once to erect more machines as fast as they possibly could upon the same principle, and he

hoped within six months from that time, they should have a complete forge at work on the Danks principle. Not only were they satisfied with the economy in fuel, and the absence of waste in every way, as shown in the trials with the machine, but they were perfectly convinced of the superiority in the quality of the iron produced from it. In fact he believed puddling was better done in it than it ever was done, or could be done, by hand labour. There were two or three specimens on the table of the first puddled bar made in England by Mr. Danks's machine, also of ball-furnaced iron from the same bar, and a rail made from a Danks bloom. Those specimens were sufficient to show the results of the system, especially as applied to the production of rails. Now that rail was not made from rolled bars at all. It was simply a bloom from the Danks machine, hammered into shape, reheated, passed through the blooming rolls in the rail mill into the ordinary rail furnace, and rolled into a rail. They would gain an idea of the quality of the iron when he told them that that rail stood, without breaking, at least five times the test of ordinary iron rails. In fact no effect at all beyond bending was produced upon it by the falling blow. Every one engaged in the rail trade knew how difficult it was to get rails to stand the falling blow decently, but if the make of rails, such as that which he had just described, could be carried into practice, there would be no difficulty in that respect, and every one acquainted with the subject, who looked at it, would tell them also that it was a rail which promised to be of very great value in point of wear. As he said before, the best commentary that he could make upon the system of mechanical puddling was to tell them that his firm were going on with the erection of other machines as fast as they could.

The President then called upon Mr. Snelus to read a supplementary report on the working of Danks's furnace in America.

SUPPLEMENTARY REPORTS

ON THE

DANKS'S PUDDLING PROCESS.

THE SCIENTIFIC FEATURES OF THE PROCESS,

BY MR. GEO. J. SNELUS, ASSOCIATE ROYAL SCHOOL OF MINES.

I have now the honour of presenting as complete a report on the scientific aspects of this process, which, as one of the Commissioners to America, was witnessed by me, as the time at my disposal has allowed. The consideration of the results obtained has involved the investigation of questions, which, at first sight, may not appear to be strictly within my capacity as a reporter upon Mr. Danks's process, but it was hardly possible to avoid them, and they are of such wide interest that I feel sure the Iron and Steel Institute will not consider the time wasted which I have bestowed upon this portion of the subject. I refer more particularly to the questions as to whether silicon is capable of reducing oxide of iron to the metallic state, what proportion of silicon, sulphur, and phosphorus usually shown in analyses of puddled bars, and like products, is really combined with the iron; and whether any, or all of this will pass into combination with iron, when the puddled bar

is melted, either *per se*, or with a certain proportion of pig iron. This latter question is highly important with reference to the production of steel ingots, by using wholly or partially the iron puddled in the machine from a class of pig that would not be fit for steel by any of the present processes, on account of the phosphorus which it contains. The consideration of the best method of working the process necessitates a slight review of the manufacture of pig iron in connection with this report.

I. Theory of the puddling process :—

Pig iron, as is well known, is essentially a compound of metallic iron with carbon, in sufficient quantity to confer upon the product fusibility at a moderately low temperature, and comparative absence of malleability. A few other elements are very prone to unite with the metallic iron during the process of reduction in the blast furnace at the same time that the carbon does, notably, silicon, sulphur, phosphorus, and manganese. As it is impossible, under existing circumstances, to use materials in the blast furnace which do not contain at least the first three of these elements, the pig iron produced invariably contains more or less of them. The proportions in which carbon, silicon, sulphur, and phosphorus unite with the iron depend upon the nature of the charge, and the burden of the furnace.

Nearly the whole of the phosphorus in the ore, fuel, and flux, will, under any circumstances, be found in the pig iron produced, but the proportions of carbon, silicon, and sulphur, which unite with the iron are more under the control of the blast furnace manager, and it is possible to produce a pig iron, which shall be comparatively free from either silicon or sulphur.

Thus, if the iron be worked very grey and the slag very basic by means of an excess of lime, the sulphur, as is well known, will pass almost entirely into the slag; but these conditions favour the reduction of silica and the appearance of silicon in the pig. On the other hand, by using a heavy ore burden, with materials to produce a slag containing about 36 per cent. silica, 47 per cent. lime, 17 per cent. alumina, and a very white iron, the silicon may be reduced to an extremely low point, but then sulphur passes in large quantity into the iron. Pig iron pretty free from silicon may be obtained by using an ore comparatively free from quartz,

such as the red Bilbao, hereafter mentioned. Usually a medium course is followed, and from 1 to 4 per cent. silicon passes into a grey pig, with only a few tenths per cent. sulphur, and from $\frac{1}{4}$ to 1 per cent. silicon, with about the same per cent. sulphur, passes into a white pig. Iron, with small quantities of carbon and silicon, comes from the furnace, usually less hot, and sets more rapidly than when it contains larger proportions of these elements, and the carbon is therefore sealed up in the occluded condition in the first case, and the metal is white, while in the latter case the time which the metal takes to set, allows of the separation of the carbon as mechanically intermingled graphite. As a rule, the more silicon the iron holds in solution, the more readily will the carbon be thrown out of solution.

Now, the object of the puddling process is to remove one and all of these foreign elements, and leave, as nearly as may be, pure iron. This is done by submitting the iron to a process of oxidation, whereby the carbon is converted into either carbonic oxide or carbonic acid, the silicon into silica, phosphorus into phosphoric acid, and manganese into manganous oxide. Whether the sulphur is oxidized and subsequently changed, or merely passes into the slag as sulphide of iron, I am unable to say. It is usually tabulated as sulphide of iron in the slag. In the old process of puddling the oxygen for this purpose is obtained partly from the fettling employed, and partly from the current of free oxygen that enters at the working door, and passing over unprotected iron, converts part of it into oxide, which again re-acts upon the metallic bath during the rabbling process. In the Danks's furnace, on the other hand, from the position of the working door and the nature of the furnace and the lining, the whole of the oxygen is obtained from the fettling.

Now when the carbon is burnt by free oxygen, it can have no effect in reducing oxide of iron, but where the carbon is oxidized at the expense of the solid oxygen of the lining, the oxide of iron containing it must be reduced, either to a lower state of oxidation, or, as is almost certain, to metallic iron, which increases the yield of metal. It appears also that under these conditions the carbon is oxidized to its highest point (I did not notice any blue jets of carbonic oxide during the boiling process), and, therefore, gives out

its maximum duty. Thus one part of carbon acting upon peroxide of iron and converted into carbonic oxide would produce $3\frac{1}{9}$ parts metallic iron, but if carbonic acid is produced $6\frac{2}{9}$ metallic iron would be obtained.

With regard to the power of silicon to effect the reduction of oxide of iron, some doubt has been expressed, and, as far as I am aware, the direct experiment has never been made. I have, however, made the following experiment, which I think proves the point conclusively:—5 grammes pure crystallized silicon were reduced to powder, and intimately mixed with 8 grammes Bilbao ore. The mixture was placed in a lime crucible, which was embedded in well-burnt lime in an iron crucible, and exposed in the muffle of a Siemens steel furnace for two hours. When opened, a bulky residue of silica was obtained, interspersed through which were fine metallic particles, and some small fused shots of metal. These were separated by the magnet and by washing, and were found to possess metallic lustre, to reduce copper salts to the metallic state, and to give off hydrogen when acted upon by acids. I have not yet further examined them, but hope to do so, and to communicate the result to the Iron and Steel Institute.

As, therefore, solid silicon is capable of effecting the reduction of oxide of iron, it is almost certain that liquid silicon, as it exists in molten pig iron, must have the power to do so too.

It is well known that phosphorus possesses the power of reducing many of the metals from their salts, but I am not aware that it has been proved to have this power upon oxide of iron. However, from the preceding experiment upon silicon, and the known avidity of phosphorus for oxygen, I am inclined to think that it has this power; but I have not yet made the direct experiment.

The same must be said about sulphur. There is, however, some evidence bearing upon this point, as Dr. Percy had the experiment made of heating together sulphide and oxide of iron, and found that, while no metallic iron was produced, magnetic oxide was formed, and sulphurous acid given off. Where an excess of oxide of iron is present, I believe this to be the ordinary reaction.

Metallic manganese appears, from the accompanying analyses, (see Derbyshire and Cleveland irons) to be completely oxidized, and I have little doubt its place is supplied by metallic iron.

The following calculations show the probable amount of iron produced by the part of each of these elements:—

C to CO.

6 C requires 8 O to form CO.

8 O derived from $Fe_2 O_3$ gives $18\frac{2}{3}$ Fe.

1 C yields $3\frac{1}{9}$ Fe.

C to CO_2

6 C requires 16 O to form CO_2.

16 O derived from $Fe_2 O_3$ gives $37\frac{1}{3}$ Fe.

1 C yields $6\frac{2}{9}$ Fe.

Si to SiO_2

14 Si requires 16 O to SiO_2.

16 O derived from $Fe_2 O_3$ gives $37\frac{1}{3}$ Fe.

1 Si yields $2\frac{2}{3}$ Fe.

P to $P_2 O_5$.

31 P requires 40 O to $P_2 O_5$.

40 O derived from $Fe_2 O_3$ gives $93\frac{2}{3}$ Fe.

1 P yields just over 3 Fe.

S to SO_2

16 S requires 16 O to SO_2.

16 O derived from $Fe_2 O_3$ (the $Fe_2 O_3$ being converted into $Fe_3 O_4$) requires 480 $Fe_2 O_3$ and gives 464 $Fe_3 O_4$.

1 S yields nearly 18 $Fe_3 O_4$ and requires 30 $Fe_2 O_3$.

Some sulphur passes into the cinder as Fe S, but what proportion or how the reaction occurs I have not yet made out.

One part metallic manganese oxidized would yield nearly one part metallic iron.

It will thus be seen what a great advantage, in point of yield, it is to obtain the oxygen from the solid lining of the furnace. There is another advantage obtained by the revolving furnace, and that is, that every part of the molten iron is brought into more immediate contact with the oxide of iron than can be possibly done by rabbling.

II. Mode of Fettling.—The revolving chamber, as has been already described, is made with longitudinal wedge-shaped recesses, which act mechanically in retaining the initial lining in its place. This initial lining, which is composed of any ore free from silica, ground up and mixed with lime cream, is put in like mortar; and when dried, becomes a refractory and sufficiently cohesive material to allow of the fettling being melted upon it without either melting itself or breaking away from the plates. It is advisable to use an anhydrous ore for mixing with the lime, as when a hydrate is used and the water of combination driven off, the mixture becomes rather crumbly.

We found this to be the case in putting the initial lining into No. 4 furnace, where the bridge was divided vertically into three sections, one of which was lined with lime and Iron Mountain ore, the other with lime and Purple Ore, and the third with lime and Bilbao ore. This last crumbled away in part, while the first retained its shape very well, and the second very fairly. Still even Bilbao answered its purpose, and stood very well in the body of the furnace.

Upon the initial lining, a quantity of any ore free from silica is melted. It is of no importance for this purpose that the ore should be without water of combination, as that of course soon disappears. Into the melted bath of ore, large solid lumps are thrown, and these being cold, cause the melted ore to set round them, and so fix them firmly, producing a rough internal lining, and thereby affording a greater amount of surface to act upon the iron. It is not only necessary that these lumps should be moderately free from silica and refractory, but also that their texture shall be such that they do not crumble by heat, as was found to be the case with Ilmenite. Tap cinder from a "cinder bottom," that is, cinder which runs from a heating furnace where a little bath of oxidized iron is used to protect the bottom plates instead of sand, fulfils all the conditions required of the ore for melting and for lumps; and where this can be had there is no need of seeking further for fettling. Where, however, this cannot be had, and ores free from silica are available there is no need to resort to this; but on the other hand, where ores free from silica are expensive, it would no doubt pay to oxidize scrap iron, or even puddled ball, and so make a proper oxide purposely. The scrap iron used by Mr. Danks merely serves this purpose.

III. The ores taken out by the Commission were Ilmenite, Purple Ore, Pottery Mine, Bilbao, Lisbon, and Marbella.

Ilmenite is a titanic iron ore. The sample taken out contained about 40 per cent. metallic iron and 25 per cent. titanic acid. It is a highly refractory material, but was found to crumble by heat, and so did not answer well for lumps, but independent of this fault, the fact of its containing TiO_2 led me to condemn it, since TiO_2 acts in many cases like silica, and the large quantity which I find in the analyses of the puddled bars, made while fettling with this material, show that it is not suitable for the purpose.

Purple Ore.—This is the residue obtained from cupriferous pyrites, after extracting the sulphur and copper, by the well known processes.

Its composition when dry is:—

Peroxide of iron	94·60
Lead (as sulphate)	·75
Copper	·30
Sulphur	·32
Insoluble residue	4·02
Phosphorus	absent
Soda	·10
	100·00

It is therefore rich in iron and moderately free from silica. It answered well for melting, to form the bath.

Pottery Mine.—This is a calcined Staffordshire ironstone. It answered for melting, but from the large quantity of earthy matter which it contains, which tend to leave a bad cinder in the ball, I think there are plenty of other ores that serve the purpose better.

Bilbao.—This is the ordinary red Bilbao which is now being introduced so extensively into England. Its average composition is :—

Bilbao Ore (raw.)

Fe_2O_3	72·322
FeO	...
Al_2O_3	1·042
MnO	1·201
CaO	3·274
MgO	·171
S	trace
SO_3	...
P_2O_5	·089
SiO_2	5·054
CO_2	4·150
Comb. H_2O	4·242
Moisture	7·770
	99·315
Iron	50·63

It is a hydrate of peculiar constitution, since it contains only about half as much water as brown ores. It corresponds in composition and character to the mineral Turgite. It answers very well for melting, but the water of combination rendered it too porous for lumps.

Lisbon Ore.—This is a mixture of magnetic oxide with brown ore. It was taken out under the idea that moderate freedom from silica was the only requisite for fettling ore. As will be seen from the subjoined analysis, it is quite as free from silica as the next ore, but the admixture of brown ore rendered it friable when used for lumps, and this will account for the large quantity of it used in No. 6 furnace, where it was tried both for lumps and for melting. For the latter purpose it answered well enough.

Lisbon Ore.	Dried at 100°C.
FeO	4·000
Fe_2O_3	80·285
Al_2O_3	2·665
Mn_3O_4	1·150
CaO	tr.
MgO	1·261
SiO_2	5·000
P_2O_5	·038
S and SO_3	tr.
Comb. H_2O	5·615
	100·014
Iron	59·00

MARBELLA.—This is a tough compact magnetic ore, and was found to stand very well indeed for lumps. For this purpose it answered nearly as well as the celebrated Iron Mountain ore. It would no doubt have answered well for melting, but our limited supply prevented our trying it for this purpose. It has the following composition:—

Marbella Ore (Raw.)	
Fe_2O_3	63·50
FeO	22·21
Al_2O_3	·83
MnO	trace.
CaO	1·98
MgO	1·41
SiO_2	7·78
Water	2·00
S, SO_3, CO_2 and P_2O_5	traces.
	99·71
Iron	61·65

IRON MOUNTAIN ORE.—This is a very dense hematite exceedingly tough and pure. It occurs in very large veins in Porphyry which form a hill about 200 feet high, known as the Iron Mountain of Missouri. It is worked to a depth in some places of 150 feet, and the main vein has a width of 40 feet. The lode runs east and west. The company working it have put out as much as 1,180 tons per day, but average about 600 through the year. It is delivered on the Mississippi, at St. Louis, at 5½ dols. per ton. There are other lodes of rich ore running parallel to this one a few miles distant, and forming what is known as Pilot Knob, but the ore from these is more slaty in character and does not fetch so high a price. We found the Iron Mountain ore in use at Chattanooga, although it costs there 11½ dols. per ton, as they had not yet succeeded in getting any other ore to stand so well for fettling.

From the above remarks it will be seen that Mr. Danks was peculiarly fortunate in having at his command about the best

material for his purpose; but that there are plenty of other ores which will answer; and where these fail, an artificial material can be produced, and is often obtained as a bye product, which will do for all purposes.

IV. The mode of firing adopted by Mr. Danks is an important item in his plans, and helps towards the success obtained. It gives the puddler a complete control over his fire, enabling him to urge it just when wanted, or to stop combustion altogether, if required. Also, being worked by a blast, there is a plenum of pressure inside, and the entrance of air at the bridge joint, which would tend to waste the iron, is prevented. The large quantity of fuel employed would no doubt be a serious item were it a necessity, but it is not, for the following reason:—It will be seen, from an examination of our diaries, that it takes from 30 to 50 minutes to melt the charge of 600 lbs., while half-an-hour or less suffices to puddle it. It is at once evident that the puddling furnace is a bad melter of the iron, and, therefore, very wasteful of fuel for this part of the operation. The mere melting of the iron ought to be done elsewhere. By this means nearly half the fuel could be saved, and twice the number of heats obtained in the same time.

V. General Description of the Puddling Process.—The pig is usually charged directly a heat is drawn and with it a large quantity of squeezer or roll cinder. This cinder varied a good deal in composition from time to time, but a fair sample taken on two days contained—

Total iron	59·5	
Insol. residue	14·4	mostly bits of brick, &c.
Phosphorus	1·04	
Sulphur	·20	

There was a small portion of iron in the metallic state interspersed through the cinder. This was estimated roughly, and gave 1·40 per cent. In some cases far more of this cinder was used than would be formed in the process. Thus the average for No. 4 furnace was 6 cwts. 3 qrs. 19 lbs. per ton of puddled bars, while it was still higher on No. 6; but since we found that the blooms lost only about 60 lbs. on re-heating and rolling into bars, and it is probable that another 60 lbs. would cover the loss during the squeezing of the puddled ball (we were unable to estimate this directly, because the

balls from other furnaces were worked at the same squeezer), about 120 lbs. would be all that would be formed by us, per, say, 650 lbs. puddled bar produced; or roughly about 420 lbs. cinder made per ton of puddled bars against 785 lbs. used; so that unless an extraneous supply could be obtained, less would have to be used, or its place supplied by something else. The object of its addition is to form a covering for the iron to protect it from oxidation by any free oxygen that may enter the furnace, since it melts quickly. It also no doubt aids the fettling, because when the iron is molten and this cinder containing oxide of iron, floating on the top, oxidation of the carbon, silicon, &c., in the pig is effected by it, and a corresponding quantity of metallic iron reduced, thereby saving the lining of the furnace to this extent. Further, as it contains less phosphorus than the slag formed from a phosphoric iron would do, it serves to dilute the cinder and render it more uniform. This, however, is a doubtful advantage when such pure iron as the tin-plate pig is being puddled, as then the reverse is the case. It is not, however, an absolute necessity, and it will be seen that several charges of white iron were worked without any cinder at all, and the yield of puddled bar was about the same as when cinder was used, but, no doubt, the furnace lining was attacked more rapidly.

After the iron was all melted, a jet of water was directed against the lining, on the descending side, in order to chill a portion of the cinder, and to cause it to be carried under the molten iron. I believe the jet of water has the further effect of carrying off sulphur from the cinder, since it is well-known that this was the result in Parry's steam refinery, but I have not yet had time to follow up this point.

When grey pigs were being worked it took about 10 minutes from the time the pig was melted till the cinder was tapped off, and the boiling process commenced. It appears that the greater part of the silicon and a large portion of the sulphur and phosphorus are oxidized at this stage, and their products are, therefore, wisely removed in the tap cinder. With white irons, which generally contain but little silicon, this desilicizing stage is very short, the iron commencing to boil within two minutes of the time when it is all melted. It was partly on this account, that no, or very little squeezer cinder was used during the puddling of these pigs. With

grey irons very little of the carbon is oxidized until most of the silicon has been removed, but as soon as the cinder has been tapped off, the vessel set revolving, and the fire urged, the irons begin to boil violently, and the carbon quickly disappears. Comparatively little cinder is formed during this part of the process, and this is taken out in the spongy ball, so that the furnace is left nearly dry for the next charge.

VI.—Analysis of the Pig Iron used and Metal and Slags Produced.—The time at my disposal has been insufficient to make as complete a series of analyses as I had intended, but I have endeavoured to take up the most important points, and to spread the investigation so as to embrace all the iron worked. At the outset, I was beset with a difficulty which I have only been able partly to overcome, by a circuitous method. I have in a previous paper, to this Institute, expressed my opinion that a large portion of the silicon, sulphur, and phosphorus which analyses show to exist in puddled iron, is there as oxidised products in the interposed slag. From the imperfect squeezing which the blooms underwent, the quantity of this interposed slag is rather large, and it became important to try if possible to determine its amount. This is also needed in order to calculate the yields.

Unfortunately, so far as I am aware, no satisfactory method of determining this slag has yet been discovered, and thus we are unable to say absolutely how much phosphorus is really in combination with the iron, and how much in the slag. This is an extremely important point, but although I have spent a good deal of time in the investigation, I have not yet found an agent which will attack the metal and its alloy and leave the slag intact.

By applying the method of mechanical analysis, explained in my paper on "The Condition of Carbon and Silicon in Iron and Steel," that is, by pounding the borings from the puddled bars in a steel mortar, and then sifting them through a very fine sieve, I have been enabled to separate a large portion of this interposed slag, with its silica, sulphur, and phosphorus. The slag being brittle becomes crushed to powder, while the metal merely flattens out, so that the fine portions contain a large quantity of slag, and the coarse particles are comparatively free from it. A similar expression of slag takes place of course in the after process of manufacture, but

I thought it best to deal with the puddled bar alone than to follow the iron through the subsequent stages of working.

I have endeavoured to solve the question of how much phosphorus and silicon are really combined with the iron in two ways, 1st, by examining the actual slag which is carried out in the puddled ball, assuming that what remains in the bar has the same composition; and 2nd, by melting some of this bar with its interposed slag in a crucible, in a Siemens furnace, and analyzing the melted product, assuming that what is there as slag will simply float to the surface, while any phosphorus that is combined will remain so.

I have been aided in the first method by the presence of what would otherwise have been an intolerable nuisance, since its estimation has given a very great deal of trouble. I refer to the titanic acid, derived from the ilmenite. A good deal of this has become intermingled and combined with the other constituents of the slag, and as such is found in the analyses of the puddled bars, and in all samples which were in a pasty condition when taken. From the fact that no titanium is found in the samples which were fluid when removed from the puddling furnace, and from the conditions of the process and the known difficulty of reduction of titanic acid, I assume that all the titanic acid that is found in the puddled bars is there as slag, so that by ascertaining the composition of the slag itself, as obtained from portions of the puddled ball, I am enabled to deduct from the puddled bar, the proportions of silicon and phosphorus due to the interposed slag, and thus arrive approximately at the quantity actually in combination with the metal.

In order to solve the question by the second mode, 5lbs. 2oz. of $\frac{A}{6}$ puddled bar (Cleveland) were melted in a plumbago crucible, in a Siemens furnace, and gave as nearly as could be obtained 4 lbs. 14 ozs. melted product, showing a loss of 4·8 per cent. and gave on analysis ·424 per cent. phosphorus and only ·056 per cent. silicon. This, as will be seen by the following analyses, corresponds fairly with the results obtained by the first method of investigation.

CLEVELAND IRON.

Metal.

		$\frac{A}{1}$ Pig Iron.		$\frac{A}{2}$ Melted Pig.	$\frac{A}{3}$ Partly Refined.	$\frac{A}{4}$ Partly Refined.	$\frac{A}{5}$ Puddled Ball.	$\frac{A}{6}$ Puddled Bar.
Iron		93·195...		95·030...	96·460...	98·088...	98·398...	97·129
Carbon............	2·60 } Gr. 2·62 } ·57 Comb.	3·180...	1·38 Gr. 1·45 Comb.	2·830...	Comb. 2·800...	1·170...	under ·150...	under ·150
Silicon	1·232 } 1·241 }	1·236...		·821...	·200...	·051...	·098...	·144
Sulphur	·110 } ·113 }	·111...		·096...	...	...	...	·036
Phosphorus	1·492 } 1·492 }	1·494...		·913...	·582...	·519...	·452...	·468
Manganese		·634...		...	...	...	...	·144
Titanic acid ...		...		...	...	...	...	·940
		99·850...		99·690...	100·042...	99·828...	99·088...	97·911

Slags.

	$\frac{A}{3}$ Tap Cinder.	$\frac{A}{5}$
$Fe\,O$	—	56·571
$Fe_2\,O_3$	—	6·857
$Si\,O_2$ }	21·54	6·730
$Ti\,O_2$ }		18·500
$P_2\,O_5$	2·353	2·770
S	·387	·207
		91·635
Iron	60·34	48·8

REMARKS.—A considerable quantity of squeezer cinder was put in with the pig, probably from 300 to 400 lbs. $\frac{A}{2}$ was taken when the pig had all melted, 40 minutes after charging.

$\frac{A}{3}$ taken 10 minutes later, and just before the cinder was tapped off. The cinder analysed was part of the tap. $\frac{A}{4}$ taken 10 minutes after the last. The iron had been boiling well for four minutes, and was just beginning to get pasty. The silicon is now reduced to its lowest point, but there is still a considerable quantity of phosphorus. $\frac{A}{5}$ A piece of the puddled ball broken off in the furnace seven minutes after $\frac{A}{4}$. It was full of cinder, and it was only after repeated pounding and separating by a magnet that the sample was analysed. From the presence of titanic acid, and the fact that the silicon is higher than in the previous sample, it will be seen that it still contains some cinder, but less than is in the puddle bar. The slag is that obtained from this sample. It is very feebly magnetic, and contains a large percentage of protoxide of iron. $\frac{A}{6}$ Puddle bar. This contains some phosphorus, but not so much as is generally left in this class of iron by the ordinary puddling process. The large quantity of titanic acid and small per cent. iron (97·129) shows that there is a good deal of interposed slag; and, indeed, this can be seen on the fracture of the bar. *This is, however, entirely the fault of the squeezing and not of the puddling.* As we mentioned in our previous report, the squeezer was driven through the puddle bar train, and the weakness of the latter made it dangerous to use the hammer on the bloom as much as was desirable. This fault runs through the whole series, and makes the puddled bars appear more impure than they really are. The bar probably has the composition given below, in which the slag is calculated from the quantity of titanic acid found in the bar, as compared with the quantity in $\frac{A}{5}$ slag.

		$\frac{A}{6}$ Bar. Calculated probable absolute composition.	Calculated probable composition of the metallic portion.	Composition of the metal after melting in Siemens furnace.
Metallic Alloy.	Iron	94·699	99·543	—
	Carbon ...	—	—	—
	Silicon ...	—	—	·056
	Sulphur ...	·026	·029	—
	Phosphorus	·408	·428	·428
Slag.	Protoxide of iron	3·124	—	—
	Sulphur ...	·010	—	—
	Phosphoric acid	·140	—	—
	Silica ...	·330	—	—
	Titanic acid	·920	—	—
		99·657	99·998	

STAFFORDSHIRE IRON (CONEYGREE.)

Metal.

		C_1 Pig Iron.		C_2 Melted Pig.	C_3 Partly Refined.		C_4 Puddled Bar	C_4 Coarse Puddle Bar.	C_4 Fine Puddle Bar
Iron		93·298 ...		95·680 ...	96·548 ...		95·749 ...	98·43 ...	89·315
Carbon............	2·55, 2·64 Gr.; ·15 Comb.	2·745 ...	1·29 Gr., 1·26	2·550 ...	Comb. 2·500 ...		— ...	— ...	—
Silicon	2·258, 2·249	2·253 ...	·914, ·928	·921 ...	·270 ...		·382 ...	·191 ...	·905
Sulphur	·135, ·126	·130 ...		·113 ...	·072 ...	·049, ·051	·050 ...	— ...	—
Phosphorus	·629, ·636, ·632	·632 ...	·374, ·342	·358 ...	·295 ...	·243, ·250	·246 ...	·215 ...	·396
Manganese	·922, ·907	·914 ...		·432 ...	·180 ...		·158 ...	— ...	—
Titanic Acid ...		— ...		— ...	·050 ...		1·200 ...	·325 ...	2·520
		99·972		100·054	99·915		97·785	99·161	93·136

	C_2	C_3 Tap Cinder.
$Fe\,O$	68·91 ...	63·900
$Fe_2\,O_3$	2·00 ...	3·55
$Si\,O_2$	12·63 ...	15·750
$Ti\,O_2$	8·75 ...	10·890
S	·33 ...	·355
$P_2\,O_5$	·63 ...	·932

$Al_2\,O_3$, $Ca\,O$, $Mg\,O$, $Mn\,O$, &c., not estimated.

REMARKS.—C_2 was the sample taken after all the iron had melted one hour from charging. In consequence of the iron being

melted so slowly, the refining process has proceeded with a portion of the iron, and the silicon has already been reduced to one-half, and other elments in proportion.

C_3 was taken five minutes after C_2, and merely all the silicon has now been removed, and more than half the phosphorus and sulphur, but the iron has lost very little carbon, the "boil" not having commenced. C_4, This puddled bar contained a large percentage of titanic acid, and very low iron. It was, therefore, thought worth while to test the sample by the mechanical analysis referred to above. The borings were, therefore, pounded and sieved through No. 80 sieve, when there were obtained roughly two parts "coarse" to one of "fine," but even the coarse particles contain some slag, as might be expected.

Derbyshire Iron.

Metal.

	E_1	E_2	E_3	E_4	E_5	E_6
Iron	92·510	...	95·678	97·750	98·071	96·682
Carbon 2·753 gr. ·36 comb.	3·113	...	2·900	1·350	under ·150	...
Silicon	2·151	...	·466	·170	·221	·387
Sulphur	·016	...	·015	...	...	·049
Phosphorus ...	1·040	...	·513	·328	·226	·213
Manganese ...	1·008	...	·144	·028	...	·057
Titanic acid ...	...	...	...	·130	·520	1·110
	99·838		99·716	99·756	99·188	98·498

			E_3 Cinder.		E_5 Cinder.	
Protoxide of iron	...	...	54·55	...	52·05	...
Sesquioxide of iron	...	...	4·30	...	3·86	...
Silica	...	...	17·57	...	11·87	...
Titanic acid ...	...	...	12·40	...	14·80	...
Sulphur	...	...	·247	...	·16	...
Phosphoric acid ...	...	...	3·971	...	2·10	...
			93·088		84·84	

E_2 was taken as soon as the whole of the iron had melted, 37 minutes after charging. E_3 8 minutes later, just before the cinder was tapped off. E_3 slag corresponds to the tap cinder. E_4 was taken 20 minutes after E_3. The grate had to be cleaned between these

samplings as the furnace was working rather cold, and this, with the smoothness of the lining, will account for the length of this part of the process, the boiling period being usually much shorter. $\frac{E}{5}$ taken 10 minutes later, during the "balling." The iron being in a pasty condition, made it impossible to separate the whole of the slag previous to analyses. Hence the large quantity of titanic acid and apparent increase of silicon. Practically, the whole of the carbon had been removed at this point, as no trace of colour could be obtained by the Eggerty process. $\frac{E}{6}$, The puddled bar, as usual, contains a still larger proportion of this slag. If we assume that the slag left in the puddled bar has the composition of $\frac{E}{6}$, the results would stand thus:—

		Puddled Bar. Probable absolute composition.	Probable composition of metallic alloy.
Metallic Alloy.	Iron	93·352	99·804
	Carbon	—	—
	Silicon	—	—
	Sulphur	·037	·040
	Phosphorus	·146	·156
Slag.	Oxide of iron	4·281	—
	Sulphur	·012	—
	Phosphoric acid	·156	—
	Silica	·885	—
	Titanic acid	1·110	—

It will be noticed in this series of analyses that the manganese in the pig rapidly disappears, and is replaced by iron. There also appears to be a trifle more sulphur in the puddled bar than in the pig. This fact was carefully ascertained, but whether it resulted from some irregularity in the bar or otherwise, or whether the iron actually took up a small trace of sulphur (for it is very small altogether), I am unable to say. The fact was noticed in the analysis and carefully verified.

WELSH IRON.—*Crystalline Pig.*—This was the worst cinder pig that could be obtained, and was taken out specially at Mr. Menelaus's request to test the durability of the lining with a highly phosphoric and sulphury material. As stated in our joint report, very little difference on the lining could be observed, but more extended observation would be required before settling this point. From the nature of the chemical actions, I think that a siliceous

grey pig would wear away the lining much more than one of this class. The iron made from this very poor pig was really of good quality, and in fact very little difference could be observed between the working of puddle bar from this pig, and from bar pig a much better material to start with. The rails made from puddled bar piles did not roll well from either of these white irons, but the test was extremely severe, the draught of the rolls being very great, and the rolls in very bad condition. Both made good heads, but tore in the flanges, showing that the iron was rather more red short than that from grey pig, but whether this was caused by sulphur, which is certainly a trifle higher in these bars than in others, or from some other cause is difficult to say. Very fair rails were made from both kinds of iron, when No. 2 iron was used for the flanges instead of puddle bar, and the iron was very tough, and worked well both hot and cold. A cross end from about 60lb. rail from the crystalline pig, with a very ragged flange, placed on bearings 2ft. 6in. apart was tried under the monkey. Two 6ft. blows from the ton ball failed to do more than bend it slightly. A 12ft. blow deflected it about half an inch, and finally a blow from 18ft. tore it through the flange and web, which showed an exceedingly fibrous fracture.

The crystalline, bar pig, and tin-plate pig, which were taken from Dowlais, were analyzed from as fair average samples as could be taken from the whole bulk, and not, as in previous cases, from each separate charge.

Crystalline Pig.

		H_1 Pig Iron.	H_2 Melted.	H_3 Partly refined.		H_4 P. Bar.	Tap Cinder.
Iron............		93·881	97·475	98·831		...	Iron...............52·37
Carbon........	2·33 2·29	2·310	1·290	...		...	Silica (chiefly) 24·77
Silicon........	·905 ·886	·895	·182	·172		·333	Sulphur.......... ·37
Sulphur........	·772 ·755	·763	·251	·070	·063 ·066	·064	P_2O_5.............. 3·36
Phosphorus	2·140 2·213	2·176	·861	·407	·388 ·385	·386	
Manganese...		·115	...	...		·057	
Titanic acid.							
		100·140	100·059	99·480			

H_2 taken, 37 min. from charging.

H_3 10 „

Tap cinder taken 3 min. before H_3 metal.

Only traces of titanic acid were now found in the slag, as most of the

ilmenite had disappeared from the lining of the furnace. The puddled bar I contained a large quantity of silicon. It was therefore tested by mechanical means, and the results of the analyses of the coarse and fine portions show, in a marked manner, the large quantity of silicon, sulphur, and phosphorus existing as slag. If it had been possible to get rid of the slag in the squeezer as perfectly as is here done from the coarse part, the result would have shown in a striking manner the efficiency of the puddling machine in purifying this very poor iron. I consider the result exhibited by the analysis of the coarse part of I as highly satisfactory.

Crystalline Pig.

	I Pig iron.		I P. Bar.		P. Bar. Coarse.	P. Bar. Fine.
Iron	93·881	...	...	....	...	...
Carbon	2·310	...	...	...	...	...
Silicon	·895	·42 ·423	·421	...	·184	1·298
Sulphur	·763	...	·096	·042 ·046	·044	...
Phosphorus	2·176	·317 ·328	·322	...	·201	1·010
Manganese	·115	...	·060	...	...	...
	100·140					

Crystalline Pig.

		J I Pig Iron.				J Puddled Bar.
Iron ...	...	93·881	...	...	...	...
Carbon ...	...	2·310	...	...	...	...
Silicon ...	...	·895	...	·704 ·682	...	·692
Sulphur ...	...	·763	...	·091 ·088	...	·089
Phosphorus	...	2·176	...	·433 ·462 ·443	...	·446
Manganese	...	·115	...	...	...	·064
		100·140				

Crystalline Pig.

		J Tap Cinder.			I Tap Cinder.
Iron ...	...	54·85	...	...	...
Insol. residue	...	20·49	...	...	21·06
Sulphur ...	...	·38	...	...	·416
Phosphoric acid	...	4·22	...	...	4·279

The slag in J puddled bar is evidently higher than in I, and it is probable that the large per cent. phosphorus and silicon is in great part due to this.

BAR PIG.

		P_1 Pig Iron.		P_4 Puddled Bar.
Iron		94·850		... ...
Carbon		2·512		... ...
Silicon	1·061 1·120	...1·091		... ·312
Sulphur	·700 ·744 ·722	... ·722		... ·068
Phosphorus ...	·586 ·570 ·547	... ·567 ...	·238 ·223	... ·230
Manganese ...	·201 ·201	... ·201		... ·028

The puddled bars from these pigs, like those from the grey, all worked down into very tough fibrous material, the rails showing very little crystalline structure, but excellent fibre. What this is due to is rather obscure. I was at first inclined to think with Mr. Danks that the iron had been rendered almost free from phosphorus, or that what was left was wholly as slag, but this is not the case. It may be that the carbon and silicon being separated to a greater extent than usual, the phosphorus left does not exercise the same crystallizing action as when small quantities of these are present.

TIN PLATE PIG.

Metal.

		L_1 Pig Iron.	L_5 Puddled Bar.	L_5 P. Bar. Coarse.	P. Bar. Fine.	Wire. (Fencing.)
Iron		92·884	98·280	98·696	92·83	98·033
Carbon	1·2 3·06	Gr. 3·130	—	—	—	—
Silicon	3·248 3·229	3·238	·488	·387	1·297	·276
Sulphur	·107 ·110	·108	·019	—	—	—
Phosphorus	·220 ·213	·216	·058	·056	·160	·064
Manganese	·417 ·432	·424	·072	—	—	—
		100·000	98·917	99·139	94·287	98·373

Slags.

		$\frac{L}{2}$		L Tap.		K Cinders.
Protoxide of iron		59·14	...	—	...	—
Sesquioxide of iron ...		20·94	...	—	...	—
Alumina		1·76	...	—	...	—
Oxide of manganese ...		1·21	...	—	...	—
Lime		·25	...	—	...	—
Magnesia		·42	...	—	...	—
Sulphur		·33	...	·29	...	·135
Phosphoric acid ...	1·2 / 1·2	1·20	...	1·13	...	1·678
Silica	14·15 / 14·20	14·17	...	17·29	...	19·62
		99·42				
Metallic Iron...			...	54·02	...	53·82

The slag $\frac{L}{2}$ was much more strongly magnetic than those previously analysed, which gave a much higher percentage. Protoxide of iron. The large quantity of sulphur and phosphorus which it contains, is derived mostly from the squeezer and roll cinder used, and not from the pig, which contains very little of either. The silicon in the puddle bar is high, owing no doubt, to the interposed slag being siliceous. In order to see how far this was removed by hammering a piece of fencing wire, drawn from a billet, rolled from a hammered bloom, was analysed with the result given above. It will be seen that the silicon is not much more than half the quantity, while the phosphorus is practically the same.

Several attempts were made to estimate the slag in the puddled bars by chemical means, but it was found to be invariably attacked at the same time as the metal. Thus 25 grammes from I bar treated with diluted nitric acid (1, acid, 10, water) left 2·76 per cent. insoluble residue, which was black and scarcely magnetic. A second 25 grammes, treated the same way, left only 1·874 per cent. insoluble residue, which on analysis gave 6·3 per cent. SiO_2 and H_2 per cent., P_2O_5, containing only about $\frac{1}{8}$ the silicon, and $\frac{1}{10}$ the phosphorus found in the puddle bar.

Attempts to estimate the absolute quantity of metallic iron in the bars gave us better results. In thus proving that these samples of puddled bars contained a large portion of interposed slag, it is not

intended to intimate that puddle bar made by the ordinary method is free from it. Thus the following samples of puddled bar were considered to be very fairly puddled, from the pig of which the analysis is given, and it is evident, from the quantity of iron found, that some, but by no means all the silicon and phosphorus is present in these cases as interposed slag.

Results obtained by Hand Puddling. Two Heats.

	Pig (white) iron.	Puddle bar made from this pig.	A.		B.
Iron	94·471	...	97·702	...	...
Carbon	2·580	...	under ·15	...	...
Silicon	1·568	·541 ·550	·545	·420 ·429	·424
Sulphur	·370	·079 ·078	·078	·098 ·116	·107
Phosphorus	·896	·433 ·427	·430	·520 ·516	·518
Manganese	·115	...	...	...	...
	100·000		98·755		

VII. Consideration of Yield and Economy.—It will be seen from the tables of yield in our joint report, that white pig iron gave an inferior yield to grey. This is a point which is somewhat difficult to account for, since even if it be the carbon alone in the pig which effects the reduction of oxide of iron, the difference in the amount of carbon in grey and white irons is not so great as to account for the discrepancy. It will be noticed in the analysis of H series that a good deal of the carbon has disappeared by the time the pig has melted. This does not happen with grey pigs. The rapid elimination of carbon from white irons may be due to the fact of all the carbon being in the occluded or combined form to start with, while in the case of grey iron it has to be gradually dissolved, and possibly it does not get oxidized rapidly till it is all in solution, and then is oxidized only by the lining of the furnace. From the theoretical considerations previously advanced, and the analysis just given, it will be easy to calculate the maximum results which can be obtained from each class of pig, but it by no means follows that these results must be got, since other conditions may, and apparently do, step in to modify them.

Cleveland pig—

Carbon	3·18 × 6·22	=	19·77 Fe
Silicon	1·23 × 2·66	=	3·27 „
Phosphorus	1·49 × 3·	=	4·47 „
Iron and manganese	... ...		94·00 „
			121·51

600lbs. pig could give ... ... 729·06 iron.

Now, the maximum result obtained was 728lbs. puddled bar, and if this contained, as it probably did, 5 per cent. slag, it leaves 681·6lbs. iron obtained, against a possible result of 729·06lbs.

Staffordshire iron would stand thus—

Carbon	2·74 × 6·22 ...	=	17·04
Silicon	2·25 × 2·66 ...	=	5·98
Phosphorus	·632 × 3· ...	=	1·89
Iron and manganese	... ...		94·2
			119·11

600lbs. pig could give ... ... = 714·66 iron.

Derbyshire iron gives—

Carbon	3·11 × 6·22	=	19·34
Silicon	2·15 × 2·66	=	5·71
Phosphorus	1·04 × 3·	=	3·12
Iron and manganese	... ...		93·51
			121·68

600lbs. pig could give ... ... 730·08

Crystalline pig gives—

Carbon	2·31 × 6·22	=	14·31
Silicon	·89 × 2·66	=	2·36
Phosphorus	2·17 × 3·	=	6·51
Iron and manganese	... ...		93·99
			117·17

600lbs. pig could give ... ... 702·02

Bar pig gives—

Carbon	2·51 × 6·22	... ...	=	15·61
Silicon	1·09 × 2·66	... ...	=	2·89
Phosphorus	·56 × 3·	... ...	=	1·68
Iron and manganese		... ...	=	95·05
				115·23
600 lbs. pig ...		... ...	=	691·38 iron.

Tin Plate pig gives—

Carbon	3·23 × 6·22	... ...	=	20·09
Silicon	3·23 × 2·66	... ...	=	8·58
Phosphorus	·21 × 3·	... ...	=	·63
Iron and manganese		... ...	=	93·3
				22·60
600 pig ...		... ...	=	735·60 iron.

Although these calculations show that white iron cannot be expected to yield as well as grey pig, they prove that there must be something more to account for the different results obtained than the presence of so much carbon, silicon, and phosphorus. Probably further study may elucidate this point.

There is one fact, however, which deserves careful consideration. I noticed that the higher the temperature at which the furnace was worked, the better was the yield obtained. This is corroborated by Mr. Danks, and if the tabulated Statement No. 1 of our joint report be examined, it will be generally noticed that the first heats in the morning, after the furnace had been standing all night, gave lower yields than those later in the day when the temperature was higher, and this was not the case when the furnaces were worked during the night shift. The quantity of sulphur may have something to do with the low yield of white iron.

Whatever is the cause of the inferior result, it becomes a serious question whether it is not greater economy to produce grey iron in the blast furnace at the expense of a little extra fuel, than to sacrifice the yield of puddled bar. There is a difference of 1 to 1½ cwt. of pig between that required to make a ton of puddled bars from white and grey forge iron. When the puddling had to be done by hand it of course saved a good deal of labour, to make the pig moderately free from silicon and white, but now that the puddling

can be done by machinery economy of yield will probably lean to the side of making the pig moderately grey and siliceous. The method of doing so has already been pointed out. While on the question of yields it may be well to point out, that about 120 lbs. squeezer cinder was expressed from each puddle ball, of which no account appears in Statement No 4 (joint report).

The following balance-sheets will perhaps serve to elucidate Statement No. 4 (joint report):—

BALANCE-SHEET OF NO. 4 FURNACE DURING FIVE CONSECUTIVE SHIFTS:—

Material going into Furnace.		Material out of Furnace.	
Bilbao ...	3,711	Tap cinder ...	5,637
Marbella ...	1,880	*Oxygen ...	1,728
Cinder ...	7,997	*Carbon ...	648
Oxidized scrap	633	Puddled bar ...	23,112
Pig iron ...	21,602	Squeezer and roll cinder (say 120 lbs. per charge)	4,320
	35,833		35,445

ESTIMATE OF YIELD OF IRON FROM REDUCTION OF FETTLING.

In.		Out.	
Bilbao ...	3,711	Tap cinders ...	5,637
Marbella ...	1,880	5 per cent. cinder	
Cinder ...	7,997	in puddled bar	1,155
Oxidized scrap	633	Oxygen ...	1,728
†Silica ...	930	Squeezer and roll	
‡Phosphoric acid	494	cinder ...	4,320
	15,645		12,840
Out as *per*		Iron in pig at 94	
contra ...	12,840	per cent. ...	20,305
		Iron in puddled bar	
	2,805	at 95 per cent.	21,957
			1,652

Fettling to yield 1,652 iron.
58 per cent. iron reduced from fettling.

* Say 3 per cent. carbon in pig.
† From the oxidation of silicon in the pig taken at 2 per cent.
‡ From the oxidation of phosphorus in the pig taken at 1 per cent.

On the Manufacture of Steel by the aid of the Danks's Machine.—Our attempts to make puddled steel were not very successful, but were not extended enough. It would no doubt be possible to ball up while the iron contains some carbon, since by reference to the E series, it will be seen that the iron only contains 1·35 per cent. carbon in $\frac{E}{4}$ 10 minutes before the ball is actually drawn; and at this point the silicon, sulphur, and phosphorus are nearly as low as at any period; but I think the results would be as irregular as with ordinary puddled steel and a pig of good quality would have to be used to start with. With reference to the use of a portion of puddled bar or semi-puddled ball to form steel in admixture with a small quantity of good pig (free from phosphorus) in a Siemens furnace, two direct experiments have been made; 1st, as before stated some of the A bar was melted *per se* in a crucible when the greater part of the phosphorus was found in the melted product. 2nd, about two parts of this bar was melted with one part West Cumberland Bessemer pig containing ·03 per cent. phosphorus. The melted product obtained contained still ·269 per cent. phosphorus, so that little or none passed off in the slag. It also contained 1·18 per cent. carbon and ·42 per cent. silicon. These quantities of phosphorus would be fatal to ingot steel, but I think it quite possible, 1st, that the phosphorus may be rather more perfectly eliminated by attention to the puddling process; and 2nd, that if a pig iron be used to start with that does not contain too much phosphorus and yet would be unfit to make steel by the Bessemer process it may be so treated that from $\frac{1}{3}$ to $\frac{1}{2}$ may be used with a non-phosphoric pig in a Siemens furnace and produce a very fair result.

In summing up my conclusions, derived from a careful consideration of the whole question, I think that the Danks's puddling furnace is a complete success; that it puddles iron even better than can be done by hand; that the undoubted increase in yield places it far above ordinary furnaces, while the cost of fettling is little more than ordinary, and is far out-weighed by the increased yield; that the mode of firing is good, while the quantity that could be turned out per furnace would make one machine worth as much as three or four hand furnaces. As before stated in our experiments, the yield of coal is high (and as this part of the question is bound to be totally changed, I have not taken the trouble to examine the coal used), but I take it that either the pig will be melted in a cupola,

or what I consider would be much better, taken either direct from the blast furnace or run into a large ladle, the furnace being tapped say every two hours, and run from thence into the puddling furnaces as required. The ladle might, as at Harrisburg Steel Works, be mounted on a weighing machine, and then the quantity poured into the furnace could be regulated at will. The small number of furnaces required to work up the product of a blast furnace will enable the plant to be placed close to the furnace, as a small pig bed for occasional mishaps would be all that would be required. By this means one founder would probably be saved at the blast furnace, the cost of moulding and melting would be entirely saved. The pig iron would go into the puddling furnace much cleaner, thereby saving the fettling, and lastly, the temperature of the furnace would be kept high and the yield thereby increased.

The subsidiary tools and appliances used by Mr. Danks will no doubt be treated of fully by my valued colleagues, but I may be permitted to state my opinion that, with the exception of the plan of driving the machine by small independent trunk engines, I consider them admirably adapted to their purpose, as they enable the ball to be dealt with quickly and efficiently, the only point of weakness being that the squeezer was not in our experiment driven direct. It might with advantage be made stronger, and I think the addition of a duplex hammer to knock up the ends of the ball while in the squeezer might be an improvement, since the ball being rather heavy, its inertia is great, and only one end of the ball is affected by the present hammer. Probably, other means of dealing with this part of the question will be devised, all I wish to do, is to point out that considerable improvement may be effected in this direction.

In conclusion, I beg to tender my personal thanks to all the gentlemen in America, who so kindly aided us in our investigations, and to my assistant, Mr. W. Jenkins, for his help in making the analyses.

Mr. Riley said, that with regard to the subject—it being very important, and one to which he had turned his attention for several years almost exclusively—particularly as to the chemical composition of iron, he would like to make a few remarks upon the paper of Mr. Snelus. He was afraid the paper was too long to enable them to discuss more than a few of the points that had been so admirably brought before the meeting, and which showed such a great amount of labour, that it would take him too much time to enter into all the subjects brought forward, and he would, therefore, confine his remarks briefly to the principal elements that existed in iron, and some points having relation thereto. He had recently been making some experiments which had modified his ideas. Anyone who had read the papers of Mr. Snelus and others, would admit that they had always been led to suppose that silicon, sulphur, and phosphorus had most deleterious effects in the manufacture of iron. Silicon, especially, had always been his bugbear, and, until recently, he had always thought that the less they had of it the better; but he must say that he had been obliged to modify his opinion with reference to it, owing to some experiments that he had tried. He exhibited some specimens showing the results of experiments that he had recently made with the view of ascertaining the amount of silicon that could be put into iron, by exposing a mixture of sand, iron ore, and charcoal for two days to a high temperature in a Siemens furnace where steel was being melted for tyres. The result was an alloy of silicon and iron, containing 22 per cent. of silicon, which was the highest he could get. He had also tried to ascertain the amount of silicon that could be got into steel, and he thought it would appear to all present a remarkable fact, when he said that a beautiful working steel could be made, containing over two per cent. of silicon. He was certainly much surprised to find good steel, containing 2·07 of silicon, which turned up cast steel wheels at Messrs. John Fowler's Works at Leeds, and worked beautifully under the hammer. He expected it to go all to pieces, but there was the fact of what was done with steel containing over 2·07 of silicon. He was not prepared to explain this; but he thought they must look to the different conditions in which silicon existed in iron. There were many points in the paper in which he could corroborate Mr. Snelus, more particularly as to the difficulty he had experienced in separating cinder from puddled bar, and he

could not say that he had satisfactorily overcome that difficulty. He had tried various methods, and had partially overcome it, but not in a very satisfactory manner. With regard to titanium, about ten years ago he believed he was the first to draw attention to its existence in all clays. At that time he thought that titanium exerted an important effect upon iron; but now they had had some ten years' experience of it, and after all the experiments that he had seen, he could not say that it had any at all. He quite agreed with Mr. Snelus in what he said with regard to titanium acting very much like silicon. He had never been able to find titanium in steel, in white iron, or wrought iron, and he thought it was reasonable to assume that as he found titanium in all clays, and as he had pointed out the difficulties in detecting it and the ways of overcoming them, in testing and determining titanic acid, it was a fair inference to assume that he should find it in iron and steel if it were there. With regard to silicon in steel, he should like to see some experiments made; because he had some definite ideas upon it. His attention was first drawn to it by the failure of some steel castings used at Messrs. John Fowler's Works. Now, the question was, why had they failed? With regard to steel castings, it appeared to him that in the manufacture of them the workmen must get their metal to run, and they were apt to put too much spiegeleisen in the steel, because it made the metal run better by becoming more fluid; but it seemed to him that there should be a limit to carbon, and he would like to try the effect of a small amount of silicon upon the steel to make it run more fluid and cast better. He thought it was fair to assume that in the results he had already obtained, they might make the metal more fluid in this way, but whether they would make it more brittle or not in the attempt he could not say; that remained to be found out by practice. He was sure the members of the Institute had every reason to be grateful to Mr. Snelus for the great attention he had given to the subject, and the highly scientific manner in which he had treated it.

Mr. Fothergill, M.P., said that, as a practical man addressing practical men, he should like to state the impression left upon his mind in respect to the very important paper which had been read, but he wished first to express the great thanks they owed to Mr. Snelus for the extraordinary pains he and his colleagues had

taken in their investigation; also, for the remarkably able and clear paper which Mr. Snelus had put into our hands, supplementing the report of the Commissioners. It appeared to him that the invention under notice had every probability of revolutionising the whole trade. There was every prospect of hand puddling being gradually done away with; because, they not only had a substitute for hand puddling, but they also appeared to have, what he, for one, certainly never hoped to see, namely, a vastly improved result from the new system of puddling. Not only would they save much of the expense of puddling, but they would be to a great extent independent of the manual labour in puddling, and that was a most important item in the cost of finished iron. It was customary among members of the trade to explain their own successes, and the important yields which, as a practical man, he maintained did not exist, except in experiments. When a man asserted that he had produced a ton of puddled bars at a saving of one hundredweight per ton of puddled bar made, he must be speaking exceptionally, and, it might be, truly, but it required an amount of superintendence which could not be given to the bulk of the manufacture, and therefore such yields had nothing to do with practical results. He was speaking to gentlemen who knew as well as himself that these great savings did not exist. The real fact was they lost a fifth, a sixth, or a seventh of the material that they put into their puddling furnaces, through either the absence of the puddler from time to time, or his inattention, or his want of knowledge of his work, or from some other cause. Now, the mechanical plan, it appeared to him, was not liable to these drawbacks, except to a limited extent, and they were not only able to turn their pig iron into malleable iron successfully, but to reduce the waste. Not only so, but there was to be no waste at all; on the contrary, there was even to be a considerable gain. That was a most stupendous and a most extraordinary change, for, in fact, this plan would produce malleable iron from the ore direct. Still, he would like very much to hear something about the approximate idea of the cost of this process.

Mr. I. Lowthian Bell said that part of the subject would be given in a subsequent report.

Mr. Fothergill would drop that part of the subject. He said the

impression left on his mind was that the success of the process was established by the statements made by the practical men who had watched it. He would add that he felt much obliged for Mr. Danks's most remarkable invention, and he thought it was one that was going to produce the most amazing results.

Mr. Snelus said he had only to add a few remarks to what Mr. Riley had said about silicon in the steel. He had himself met with cases, which had been already published, of steel containing a large percentage of silicon, and he had always found that silicon produced a material exceedingly hard, and would no doubt turn up rolls, but they found that even chilled white pig iron would do that. He would ask whether the silicon steel would bear any breaking weight, or whether it had anything more than its hardness to recommend it.

Mr. Riley had not tried the breaking weight of the steel, but it had been examined by practical men, who considered it to be a first class steel. He had not made the experiments on a sufficiently large scale to enable him to answer the question more definitely. He had given the steel to practical men, and they could do anything with it that they wished, either in working, drawing out, tempering, or hammering it.

Mr. Edward Williams suggested that it would be better if the reports of the Puddling Committee were all read before entering into any discussion, and that they should consider them together. In Mr. Snelus's paper there were whole pages of statistics, and he was inclined to think that many of his puddling friends in the room would, like himself, be glad to have time to understand them better before discussing the subject.

The President then called upon Mr. J. A. Jones to read his report.

THE COMMERCIAL ASPECT OF DANKS'S ROTARY PUDDLING FURNACE,

By MR. JOHN A. JONES, MIDDLESBROUGH.

THE first report of the Commission sent to America to investigate the working of Danks's Rotary Puddling Furnace was necessarily confined to deductions drawn from the results derived from the experiments made at the Railway Iron Works, Cincinnati, and from reports obtained from other places where the machine had been in use in America. The Commission did not indulge in any speculative opinion as to the present capabilities of this machine when worked under somewhat different combinations from those which prevail at the Cincinnati Works; neither did they form any estimate of the cost of the new plant as compared with existing plant; and, further, the results in the cost of production between the Danks's and the ordinary systems were not presented in a tabulated statement before the committee. It was deemed more prudent to be somewhat reticent upon these matters, and only to offer to the committee that which was thought could not be disputed, and which was known to be, on the whole, correct and trustworthy. I propose in this short paper to deal more generally with the results, and to make such estimates and comparisons as will give a somewhat better idea of what this machine is capable of performing, and what a plant erected on Danks's system could do as compared with one of the present class.

It will be quite unnecessary to give a description of the rotary furnace, as that is now well understood by the members of the Institute.

FIRSTLY. A COMPARATIVE ESTIMATE OF THE COST OF PLANT BY THE TWO SYSTEMS.—Suppose we take the cost of a plant, as at present erected, of fifty puddling furnaces, which will include all that is necessary with a view of making puddled bars alone—the finishing mills forming no part of this estimate. The estimate will not include land nor offices, and is simply a comparison between the two systems. Then we have, say,

50	Ordinary puddling furnaces	£6,000	0	0
3	Steam hammers, with foundations	3,000	0	0
1	Forge train and foundations	1,200	0	0
30	Vertical single-tubed boilers, with fittings ...	6,000	0	0
	Steam feed pipes, and valves	2,000	0	0
	Roofing	4,000	0	0
	Railways	1,500	0	0
	Forge engine, gearing, and foundations	2,000	0	0
6	Pumps, with tank, feed-heater, house, and all connections	1,500	0	0
	Weigh bridge and weighing machines	500	0	0
2	Grinding mills, complete	600	0	0
	Floor plates and sundry castings	1,000	0	0
	Patterns, gas mains, and general tools	1,500	0	0
	Smiths' shop, stable, storehouse, fitting shop, and fittings	2,000	0	0
		£32,800	0	0

This estimated plant is capable of turning out about 600 tons of puddled bars per week, and is, as before mentioned, for the production of puddled bars alone. It is taken with pig iron as a basis at 50s. per ton with other materials and labour in proportion. No doubt the cost in the erection of ironworks varies much according to the idiosyncrasies of the engineer, and also by reason of the difference in localities. The estimate I have formed is one gathered from experience in the Cleveland district, and I think it will be found to represent fairly the cost in that locality. It includes, of course, only what the writer would call the first cost of a plant requisite for starting and conducting the works fairly. If mills were added to convert the puddled iron into rails or other articles probably the total estimated amount would have to be doubled.

I will now endeavour to give the cost of a Danks plant, having precisely the same object in view, viz., the production of about 600 tons per week of puddled bars, and the figures which can be allowed to remain as in the first estimate will appear in the one I am about to give, and only such alterations will be made as will be requisite to institute a fair comparison. It will be necessary to give an explanation here. There is little doubt that immediately we shall proceed with ten cwt. charges in the Danks machine—that was the weight which the Commissioners recommended in their telegram from America. It is also certain that ten or more heats per day of 12 hours may be obtained by this machine. Those who

have read the diaries attached to our report will have noticed the time required for the melting of the pig iron in the Danks converter. It will be found that 45 minutes, on an average, are consumed in the melting of the metal, and that only 30 minutes are required in which to puddle the iron—that is, from its molten condition into a ball ready for drawing. It is quite apparent then that a Danks converter, as a means whereby pig iron is melted, is an inferior contrivance, but as a machine whereby pig iron is puddled effectually and economically, it has more decided claims for recommendation. In order, therefore, that it may be utilized in a proper manner, it must be kept continuously puddling. That this may be done, the metal must be charged in the Danks furnace in a molten state. I have mentioned the foregoing in order to make it plain why there are such specialities as cupolas, with their attendant necessities reckoned for in the following estimate:—

12 Danks's puddling machines complete. It is assumed that 12 of Danks's furnaces will produce as much as 50 ordinary furnaces ...	£6,000	0	0
1 Squeezer, with engine and foundations	1,000	0	0
3 Cupolas, with steam-lift, blast engine, blowers, and mains	2,000	0	0
3 Steam hammers, with foundations	3,000	0	0
3 Heating furnaces for heating the hot squeezed blooms	700	0	0
12 Boilers attached to the Danks machines, with fittings, steam feed pipes, and valves	800	0	0
3 Vertical boilers attached to the 3 re-heating furnaces, with fittings	800	0	0
Steam and feed pipes, and valves	200	0	0
4 Double-flued Cornish boilers for firing, with fittings	1,300	0	0
Steam feed pipes, and valves	200	0	0
Forge train, and foundations	1,200	0	0
Roofing	4,000	0	0
Railways	1,500	0	0
Forge engine, gearing, and foundations	2,000	0	0
Tank and feed heater, with house and connections	500	0	0
Pumps, with connections, &c.	1,000	0	0
Weigh bridge and machines	500	0	0
Floor plates, and sundry castings	1,000	0	0
2 Pug mills	600	0	0
Patterns, gas mains, and sundry tools	1,500	0	0
Smiths' shop, stable, storehouse, fitters' shop, and fittings	2,000	0	0
	£34,200	0	0

So that, as far as can be roughly estimated at present, there is no great difference in the cost of erection of a Danks's puddling plant for the production of a given quantity of puddled bar in a given time, and that of a plant erected on the present system.

SECONDLY.—The writer will now give an estimate as fairly as he can, comparing the cost of production between the two systems. A comparison will first be made between our present mode of working, and the actual experiments during the week's work at Cincinnati; and afterwards, a comparison with what may be fairly expected from a plant erected with Danks's puddling furnaces and contingencies. I will preserve the basis of my estimate with pig iron at 50s. per ton, and other material and wages corresponding to that figure. Then we have—

ESTIMATE OF COST OF PUDDLED BAR BY THE PRESENT SYSTEM.

	Cwts.	qrs.	lbs.		£	s.	d
Pig iron	21	2	0	@ 50s. ...	2	13	9
Coal	24	0	0	@ 5s. 6d. ...	0	6	7
„ for other purposes ...	4	0	0	@ 5s. 6d. ...	0	1	1
Fettling	5	0	0	@ 20s. ...	0	5	0
Scraps for bottoms ...	0	2	0	@ 50s. ...	0	1	3
Wages					0	16	0
Sundries.—Bricks, fire-clay, stores, rents, rates and taxes, water, gas, office expenses, salaries, interest on capital, and other dead charges					0	7	6
					£4	11	2

This gives a total of £4 11s. 2d. per ton at the works. Now, I am quite aware that these figures will not accurately represent the cost in production of puddled bars in all parts of the kingdom; it will probably be higher in Staffordshire and Scotland and lower in Wales, the latter district having a great advantage by reason of its cheap labour, and the two former districts being at some disadvantage in the price of materials. The larger works may also be able to reduce this estimate of cost by 5s. or 6s. per ton, by reason of the large quantity turned out in a given time; and especially if they do not charge to the puddled bar the mill tap cinder, which is procured from the first heating furnaces in the mills, and which serves so well for fettling purposes.

ESTIMATE OF COST OF PUDDLED BAR BY THE DANKS SYSTEM, as watched by actual experiments at the Cincinnati Works, but with an English interpretation so far as wages and materials are concerned.

The same prices of materials are preserved here so as to keep up the comparison.

	Cwts.	qrs.	lbs.		£	s.	d.
Pig iron	18	2	25	@ 50s.	2	6	10
Coal for puddling ...	29	0	0				
„ re-heating ...	5	0	0				
„ sundry purposes	4	0	0				
	38	0	0	„ 5s. 6d. ...	0	10	6
Fettling	6	0	15	„ 20s. 0d. ...	0	6	2
Scraps	...	...		... ...	0	1	4
*Wages	...	...		... ...	0	13	6
Sundries as before estimated for various charges—see previous estimate ...	...	...		... ...	0	7	6
					£4	5	10

So that, taking the week's experiments at Cincinnati, as compared with our present system, there appears to be a gain of 5s. 4d. per ton on the puddled bars. That saving is due to the excellent yield and to less wages.

I will now proceed to make what will be called a speculative estimate of what he thinks may be done by working night and day, and especially with a relay of three sets of men working eight hours per shift, and with, of course, a different organization to that existing at Cincinnati. I wish to guard myself against anything which may appear to reflect upon the system pursued at Cincinnati. I merely wish to convey to the members of the Iron and Steel Institute that the working by one shift or turn, and consuming coal to keep furnaces alight during the night (the prevalent system in America), and also melting the pig iron in the rotary furnaces, are the drawbacks to which I allude.

* NOTE.—Actual puddling costs less at Cincinnati by 5s. per ton, but reheating and additional men at crane and forks cost 2s. 6d. per ton extra—giving 2s. 6d. per ton in favour of the Cincinnati mode of working.

A SPECULATIVE ESTIMATE OF COST IN PRODUCTION OF PUDDLED BARS BY THE DANKS'S SYSTEM, say with 10 heats in 12 hours of 10 cwt. charges.

	Cwts.	qrs.	lbs.		£	s.	d.
Cost of melting pig iron in cupolas, including wages, coke, &c.					£0	6	0
Pig iron ...	18	2	25	@50s.	2	6	10
Coal for puddling ...	15	0	0	„ 5s. 6d. ...	0	4	2
„ re-heating ...	5	0	0				
„ Firing for Steam	4	0	0				
	9	0	0	„ 5s. 6d. ...	0	2	6
„ Fettling ...	6	0	15	„ 20s. ...	0	6	2
Scraps	0	2	3	„	0	1	4
Wages					0	8	0
Sundries, as estimated before, 7s. 6d., but reduced by 2s. by repairs of brick work, furnace castings, and general repairs					0	5	6
					£4	0	6

So there appears to be an estimated margin of 10s. 8d. per ton, which may be expected to be saved over our present system of working. I think that this estimate may, on the whole, be relied upon, and I do not feel inclined to go much further into what may be expected of this machine. My estimate is perhaps over sanguine, but time alone can prove whether this is so or not.

No doubt already schemes for running in molten iron from the blast furnace, and the increase of the charge from 10 cwt. to 1 ton in weight, find busy supporters, but with these we have at present nothing to do.

The reduction of the large bloom into handy sizes, whereby puddled bars of small dimensions may be manufactured, is of great interest, and no doubt ready means will be found by those interested in accomplishing this.

THIRDLY.—The remarkable yield which results from this furnace.

One peculiar feature of this machine is its productiveness in the matter of yield. This has given rise to much speculation. The Commissioners paid great attention to this matter, and they fully adhere to the statement printed in the JOURNAL of the Iron and

Steel Institute. There will be no difficulty in reconciling the chemistry of it with the results which have been obtained, and my friend Mr. Snelus has been, or will be, able to give any explanation on that head which may be asked of him. It is no uncommon phenomenon to meet with people even now who decline to perceive that the yield in any puddling furnace can be added to by a fettling rich in iron, and low in silica. In ordinary puddling furnaces it is a common matter when fettling with mill tap cinder or Pottery Mine, or other rich oxides of iron, to get 20 cwt. of puddled bars from 21 cwt. of pig. In a paper read by Mr. Siemens, before the British Association, in August, 1868, he calls attention to the advantage in yield of puddled bar from pig iron, derived by the use of his furnaces, as compared with the ordinary furnace, and in a table of results he makes out that an ordinary furnace loses about 12 per cent. of its weight in pig, and that the Siemens Regenerative Gas Furnace loses only 3·5 per cent. He goes elaborately into the chemistry of puddling, and shows how the superior yield is obtained. The deductions drawn from his paper are, that from a given quantity of fettling, about the same amount of metallic iron is reduced in both furnaces, but that in the further stage, when the charge is beginning to cohere, his furnace has the advantage, in consequence of its flame having a less oxidizing tendency than an ordinary furnace; no draughts or inlets of air, and there being a plenum in the furnace, contributing to this. That fettling rich in iron, say from 55 to 65 per cent., and low in silica, say not exceeding 6 per cent., added to the yield of puddled bar, has been known for many years, and has been discussed in the meetings of the "Cleveland Institute of Engineers" more than five years since. And practically the fact has been acted upon for more than 20 years. Now in the Danks furnace, the facilities afforded for the reduction of the fettling are much greater than what are afforded in the old process. There is no waste of iron caused by the melting of brick-work and fireclay. The whole chamber being lined with oxides which have been melted and have been allowed to set, there is nothing to affect the quality of the iron in the shape of dripping fire-clay and bricks, and the mass of the metal is constantly being rubbed against the fettling, giving it a better opportunity for the utilisation of the fettling by reduction, and not the mere melting of it out, as is largely the case in the ordinary way. Thus

the quality and yield are improved. It is noticeable that a small quantity of cinder is tapped out of the Danks furnace, as compared with that out of an ordinary furnace. There is nothing more beautiful in this machine than its apparent almost perfect utilization of the fettling.

FOURTHLY.—THE MANUFACTURE OF RAILS AND OTHER ARTICLES FROM A DANKS BLOOM DIRECT.—The manufacture of a rail and other articles from a comparatively homogeneous slab may now be looked for with some degree of certainty.

There is a probability that the piled rail will give place to the solid bloom rail. It will be interesting to know how long such a rail will wear as compared with a piled rail. For this we must wait.

With regard to the division of the single bloom so as to enable small iron to be worked, no doubt means will be suggested whereby the blooms may be elongated and afterwards divided into suitable lengths, or the bloom may be divided on its arrival from the squeezer before it is re-heated.

We appear, then, to have come to a stage when it may be fairly expected that the heavy labour of hand puddling, with all its attendant annoyances and disputes, is on the point of gradual departure. The change will necessarily be slow, for the total overthrow of existing plant is a serious and formidable difficulty in the rapid adoption of the invention. At the same time, it is a matter for congratulation that the time has arrived when the way is clear for a much needed revolution. I would wish, in conclusion, to pay a tribute to the energy displayed by Mr. Menelaus in the endeavour to solve this same problem. It is my opinion that, had Mr. Menelaus been supplied with first heating cinder bottoms in his rail mills, the cinder derived from that source would have gone far to have helped him on to success.

It will be apparent that the mechanical arrangements of the Danks's machine are, on the whole, very superior. The flue or elbow-joint which connects the furnace with the chimney is a contrivance which deserves special remark—its easy and rapid removal enables the interior of the furnace to be got at, and on reference to the diaries of our report it will be seen how quickly the furnace is emptied of its charge, and how rapidly it is charged again; frequently it has not taken more than from a minute to two minutes to withdraw the heat and charge again.

Mr. J. A. Jones, supplementing his paper, said that, with reference to Sir John Alleyne's remarks, he might say that the machine should be kept continuously puddling, and that if the heats were divided into balls, it would take much more time to get them out and re-charge the metal. He, therefore, maintained that every means which could be devised to keep the machine perpetually puddling would tend to reduce the cost of production. It had occurred to him while Mr. Snelus was reading his analyses, to ask whether this machine could be made useful for Siemens steel process; whether the pig could be so cleansed of its impurities that the product might be run out and remelted on the Siemens hearth into steel. If Cleveland iron could be used in that way, there appeared to him to be a very good prospect in store for the trade.

The President then called upon Mr. John Lester to read his paper.

ON THE PRACTICAL WORKING

OF

DANKS'S ROTARY PUDDLING MACHINE.

BY MR. JOHN LESTER, WOLVERHAMPTON.

INASMUCH as a joint report of the Commissioners on the working of Danks's Rotary Puddling Machine in America has already been published, I trust that it will not be considered inconsistent if a little repetition should occur in connection with this paper.

It is not for me to give a description of the machine, for that has already been done, but to state what I have observed relative to its practical use and mode of operation.

I shall, therefore, proceed at once to describe, in a practical manner, the different stages of the process, and, in doing so, I shall commence with the fettling, or lining of the revolving chamber. In connection with this machine there are two linings, the first termed the initial, and the second the working lining. The material, of which the American initial lining consists, is pulverised Iron Mountain Ore and lime cream, which are thoroughly mixed together in a pug or mortar mill to the consistency of a good thick

paste or stiff mortar. I would here remark that, instead of the Iron Mountain Ore, which cannot be obtained in this country sufficiently cheap for general use, best tap cinder from either the scrap or mill heating furnace where cinder bottoms are used would answer the same purpose. Also Purple Ore, Pottery mine, or even pulverised puddled tap cinder calcined in a kiln, commonly called Bull Dog. Any of the foregoing could be employed with advantage for making the initial lining, when mixed with the lime cream, as before stated.

This mixture is built in the furnace next to the bare plates, and between the dovetails formed by the longitudinal flanges, which are cast upon the segments forming the circle of the revolving chamber. It is built about one inch higher than the flanges in order to protect them from the fire.

About one half of the circle of the chamber is thus lined at one time. This being completed, a good fire, of either wood or coal, is made upon the lining in order to dry it well, so that it will allow the chamber to turn with this to the top without its falling down.

When the first part of the lining is thoroughly dry, it is turned to the top, and the second half is put in, in a similar way to the first, and it is also dried.

This operation being complete, the furnace is then ready for lighting up.

As soon as the furnace has reached a white heat, which is obtained after the lapse of about two hours firing, the process of what is termed glazing is commenced. This is done by throwing into the furnace three or four hundredweight of hammer slag, squeezer slag, or roll scale. The fire is then urged, and when the slag is melted the heat of the furnace is reduced, and the chamber is made to revolve very slowly, so as to allow the molten slag to wash around the initial lining, which absorbs a great portion of the molten slag, and as the slag thus adheres to the lining it becomes glazed. When this is well set, the furnace is ready for the second or working lining. This is affixed in the following manner:—

The large scoop (see Fig. 1 in Commissioners' Report) is filled with pulverised Iron Mountain Ore, then lifted by means of a crane (see Fig. 8 in same report), and deposited in the revolving chamber.

The fire of the furnace is then urged with blast on in order to melt the ore, and the furnace is made to revolve from time to time,

so as to turn up the cold portions of the ore, and thus expose it to the flame. When the ore has commenced melting, the furnace again revolves slowly and continuously at about one and a half revolutions per minute, and when the whole charge is melted the machine is again stopped, and the molten ore forms a bath at the bottom of the chamber.

The elbow-joint flue is next removed, and a scoop of Iron Mountain Ore lumps is thrown into the bath of molten ore as quickly as possible. The flue joint is again adjusted, until the bath of ore is set sufficiently hard to admit another charge. This operation is repeated until the whole chamber is lined in the manner described.

I would here add that the ores which are the most refractory in character are required for this working lining. We found by our experiments in America that Pottery mine and Purple Ore small, with Marbella lumps, which qualities of fettling were among those taken out by us, stood very well, but the remainder did not answer the purpose so thoroughly. It has been ascertained by various trials made at the Tees-side Iron Works, Middlesbrough, that best tap cinder stands well either small or in lumps; also pulverised Pottery mine and Purple Ore for small. To these may be added good clean mill scale from the finishing rolls, which may itself be enriched by the addition of a little good wrought iron scrap. As soon as the working lining is completed and well set, the furnace is ready for the charge of iron.

Before describing this stage of the process, a few words may be said about the blast, which I consider is essential to the proper working of the furnace. This blast is produced by a fan or blower, and its pressure should be not more than half-a-pound. Below the fire bars there are two nine-inch apertures, through which the blast is blown, and at the back of the fire grate, and just over the fire, on a level with the bridge, are nine more about 3 inches long by $1\frac{1}{2}$ inches wide. Between these, eighteen jets of blast are blown through one inch piping. The ashpit is closed by two folding doors. The man in charge of the furnace has perfect control over the blast, and can regulate it as the charge may require.

The use of the blast in connection with puddling and heating furnaces in America appeared universal. I made enquiries of several workmen as to their opinion of its usefulness or otherwise, and they all bore testimony in the affirmative. The puddlers

stated that they could, by its means, obtain a uniform yield and quality, whilst heaters of steel ingots affirmed that they could work better by its aid, because they had a greater command of the flame, and the heat could be nicely regulated and kept mellow.

All charges we saw worked in America with the rotary furnace were of cold pig iron, which does not show it off to the best advantage, and the Commissioners are of opinion that all charges should be in a molten state when inserted either from the blast furnace or cupola. There is no doubt that great economy would be effected by this, as it would save both time and fuel, for the time taken in melting cold pig iron is as great, and often greater than that required for working after the charge is melted. It may safely be calculated that the number of heats worked in a given time will be at least one-third greater by putting in molten iron than if cold pig iron is employed.

It was stated that when the original experimental furnace was in operation, at Cincinnati, a cupola was used with very good results, and Mr. Danks has informed the Commissioners, since his arrival in this country, that two cupolas are in course of erection with a lift between them to take up the charges. The two are put up, so that if one should need repairing, the other may be used, and thus no stoppage of the work would occur.

In charging the furnace, a little more than the ordinary amount of hammer or squeezer slag is required. When the charge is all melted, the blast is taken off, and a jet or small stream of water is inserted through the stopper-hole upon the descending side of the furnace just as it comes in contact with the molten iron. For this purpose an elastic tube attached to a water pipe is used, and the water is regulated by the man who has charge of the furnace, and who inserts the water from time to time, or continuously, as the case may require. During this stage of the process the furnace revolves slowly at from one and a half to two revolutions per minute.

When the iron becomes crude, the water is stopped, and the machine also. Fire is put on, with a little blast, so as to melt again the cinder, which at this stage of the process is tapped off. Care should be taken in tapping, so that the iron may be prevented running out at the same time as the cinder, which may be avoided by lowering the tap-hole just enough for the cinder to run. This

hole should be a little higher than the level of the iron inside, the cinder being lighter, and, therefore, floating above it, would run off first. As soon as this cinder is run off, and the tap-hole stopped up, the machine is made to revolve quickly—at about eight revolutions per minute, fire is again put on and full blast, in order that there may be a very high temperature in the furnace during the time of boiling and dropping.

If the process of watering the iron and tapping off the cinder has been properly done, the iron very soon arrives at the boil. This it does very finely, much better in fact than in the hand puddling furnace. When the iron has ceased boiling and has begun to drop, the iron found upon the elbow joint should be pushed away from time to time into the furnace proper, by means of a small bar or hook, and when the metal has all dropped, the machine is stopped and the blast lowered to prepare for the operation of balling, which preparation takes some two or three minutes. This having been completed, the machine is again made to turn very slowly, at from two to three revolutions per minute, as may be decided on by the man in charge. The ball is made in about two revolutions, and after being worked at the end next the stopper hole for a few seconds with a rabble, the elbow joint is removed, and the charge withdrawn by the aid of the large fork represented in Fig. 2 of the Commissioners' joint report.

The completeness of the whole operation is greater than what had been anticipated by the Commissioners. The manipulation of the iron is just what is required for uniformity and good quality, and I am firmly of opinion that no man, nor any number of men, can work the material as thoroughly as it is operated upon in the Danks's machine. All charges that we saw worked were made into one ball, as it is by experience found scarcely advantageous to divide the iron in the furnace.

THE CAPACITY OF THE FURNACE.

At first, in connection with the experimental furnace, the charge varied from 200 to 350 lbs., then it was increased to 500 lbs., and afterwards to 600 and 700 lbs., which last weights are being worked regularly at the Railway Iron Works, Cincinnati; at the Roane Iron Works, Chattanooga; and at the Indianapolis Rolling Mills. These furnaces will work 1,000 lbs. as easily as 600 lbs. The question does not appear to be what weight of charge can the

machine work, but what quantity can be manipulated in the shape of a hot puddled ball, either by hammer or squeezer, to advantage. In the experimental furnace at the Tees-side Iron Works, Middlesbrough, a charge of molten iron was worked, which, after hammering, weighed 1,329 lbs.

I am of opinion that one ton per furnace per heat, or more if necessary, can be easily manipulated, if appliances can be procured to work the ball afterwards.

THE AMOUNT OF MANUAL LABOUR REQUIRED.

To work the furnace in America, the ordinary number of men are employed as at a common hand puddling furnace—a man and a boy. The physical labour needed is very small indeed, when compared with that spent in the old hand puddling process. Muscle was not so much wanted as intelligence and care: the hard, exhaustive physical labour of the old hand furnaceman is dispensed with, and a man may with comfort be engaged at this machine until he is 60 or 70 years of age. A greater boon than this could not be conferred upon the puddlers of the British iron trade.

LEARNING TO WORK THE FURNACE.

There does not appear to be any difficulty in this, as far as I can judge. The method of working is soon acquired, and a man of ordinary intelligence quickly becomes conversant with all the details of the operation. The great objection which attaches itself to the old hand puddling furnace is dispensed with, and in addition there is no heavy labour to perform during the short time he is mastering the working of the furnace, to prevent the proper discharge of his duty. The method is simple, the labour mere exercise, and the duties altogether very light.

THE FETTLING, LINING, AND REPAIRS OF THE FURNACE.

The initial lining never needs thorough repair unless portions of the furnace are taken out, and the working lining is easily repaired between the heats during the day, if necessary. If the furnace is in good condition at the begining of a day's work, it is often worked the whole shift without any repairs,—that is, during the time that seven or eight heats of cold charges, or eleven or twelve of hot metal are got out. The amount of fettling appeared to be small compared with the number of heats and the weight of the charges.

The experimental furnace at Messrs. Hopkins, Gilkes, & Co.'s., Middlesbrough, was put in thorough repair before starting, and

forty heats were worked, during which time it has been partially fettled five times. (*See also Joint Report, Statement No.* 9).

The rotary furnace does not burn away many puddler's tools, consequently, the blacksmith's work of repairing is not great.

There was used at the Cincinnati Railway Works during the year, with eight furnaces regularly at work, about 30 cwts., whilst at the same number of old puddling furnaces from 15 to 20 tons per year of tool iron are used.

All puddled blooms after passing through the squeezing apparatus are reheated before rolling.

The size of the forge rolls train is 18 inches, three high, and two sets of rolls, the first for blooming and forming, and the second for finishing the bar.

At the Cincinnati Works a very good contrivance is used for cutting down the puddled bar while hot. It consists in a number of small carrying rollers placed in small stands or carriages on a line with the last groove or pass of the rolls. The puddled bar is delivered on to these small rollers, and by them it is carried to the shears, then by the aid of a small internal friction wheel, connected with a horizontal shaft with bevel wheels attached to the carrying rollers, the puddled bar of about 6 cwts. is made to pass between the shears, and is thus cut up. The iron is then taken upon a bogie, weighed, and put in readiness for piling in the mill. The whole of the labour is performed by two youths, who thus cut up and weigh for eight rotary furnaces, their time being only half occupied.

The squeezer at these works, and also that at Chattanooga, is worked off the end of the forge train.

The iron made in the rotary furnace stood the heat and rolled well in all the subsequent stages of the finished iron manufacture, such as rails, plates, sheets, strip, and small sizes of squares, rounds, Tee iron, and wire rods.

From what I saw in connection with the working of this furnace in America, and also from what I have observed when examining the experimental machine at the Tees-side Iron Works, Middlesbrough, I have come to the conclusion that practically the Danks's Rotary Puddling Machine is a great success.

THURSDAY, 21st March, 1872.

The President, having briefly opened the meeting, called upon Mr. Siemens for some observations upon the papers read on the previous day, upon Danks's Rotary Puddling Furnace.

Mr. Siemens congratulated the members of the Iron and Steel Institute on the very able reports which they had received on the subject of Danks's Rotary Puddling Furnace. He had listened to these reports with great interest, and it seemed as though the facts brought out conclusively proved the value of the apparatus that had been brought before them. That was not the first attempt at a rotating puddling apparatus, as they well knew. He had, many years ago, seen the apparatus erected, at Dowlais Works, by Mr. Menelaus, and he looked with regret at the difficulty which prevented its practical success. That difficulty had, to all appearance, been overcome by Mr. Danks, by the introduction of a judicious fettling material. In the report, mention was made of one or two points which called for remark on his part. In one of them, by Mr. Jones, a paper, "On Puddling Iron" was mentioned, which he (the speaker) read, some years ago, before the British Association, setting forth a theory of puddling which had been much criticised by practical ironmasters, but which was very fully confirmed by the results obtained in the Danks furnace. The reports in question expressed some surprise at the greater yields realised in puddling grey iron than in puddling white iron. Now, he would submit that his paper furnished a complete explanation of that result. He there endeavoured to prove that puddling was, strictly speaking, a chemical reaction between fluid cinder and fluid cast iron, and he showed that for every pound of carbon in the metal, 3·5 pounds of metallic iron had necessarily to be reduced and added to the charge. In like manner, for every pound of silicon in the metal 2·8 pounds of metallic iron had to be produced. If, therefore, his theory was correct, it followed that a pig metal, rich in carbon and in silicon, would give greater yields than a metal containing those foreign substances in smaller proportion, or that grey pig metal would produce larger yields than white iron. The report also made mention of the possible application of this furnace to what was called the "Siemens-Martin" process. He could not fall in with that view. It would be very difficult to realise such a temperature

in a rotating furnace as was required for carrying out a process in which they had five or six tons of almost pure iron in a fluid condition—iron containing about one-tenth per cent. of carbon. Another fatal circumstance would be that the lining of the Danks furnace was composed of oxides of metal, and in the presence of oxides of metal, they could not have fluid mild steel. The steel would immediately part with its small percentage of carbon, and become wrought metal. Therefore, it could not be applied, he felt certain, to carrying out that process. But he might remark that, some years ago, his attention had been directed towards a rotating apparatus, not for puddling, but for accomplishing just the reverse operation—that of reducing oxides into the metallic condition; he had steadily followed out those experiments, and, before long, he might have the pleasure of bringing them before the Institution. Before sitting down, he wished to express that he was entirely satisfied with the able, and evidently strictly impartial, reports which they had received.

Mr. I. Lowthian Bell said he should like to put one question to Mr. Siemens, who mentioned that the richer the pig iron was in silicon, the better the yields. That, he supposed, he ascribed to the action of silicon upon the oxide of iron. But he (the speaker) believed a very general impression prevailed amongst puddlers that that could only be true to a moderate extent; because the silicon by taking the oxygen was changed into silica, and that, not being able to exist in a puddling furnace in its uncombined state, combined with oxide of iron, and was thereby a source of waste.

Mr. Siemens, in reply, stated that with regard to the carbon, the result had been proved, in the most conclusive manner, by experiments which he himself had made in the regenerative gas puddling furnace The richer the pig iron was in carbon the greater was the yield of wrought metal produced. The same chemical reason and the same practical result applied to silicon, although he would quite admit certain drawbacks, which Mr. Bell had alluded to, to the presence of much silicon in the pig metal The silicon in the pig metal had to be combined with oxide of iron to form a tribasic slag, and this oxide of iron had to be supplied by the fettling. Therefore, if they puddled an iron containing much silicon they would require an extra amount of fettling to dissolve the silicon afterwards in the slag, and in the absence of this extra supply of

fettling the operation would not progress favourably; but the chemical reasoning still held good. They could obtain from pig metal rich in silicon, a larger yield than from the same pig metal containing no silicon, the simple reason being that the atomic weight of silicon was considerably less than the atomic weight of iron. In his paper read before the British Association, he had shown that in puddling ordinary forge pig iron the theoretical increase of weight was about 8 per cent., and that he had already obtained weight for weight in practical puddling—taking the average result of six months working—without using more fettling ore than was necessary, under all circumstances, to accomplish the operation.

Mr. Snelus thought he could also corroborate Mr. Siemens in what he had stated, and perhaps carry the point a little further. In the ordinary puddling furnaces, he believed, the reason why the silicon did not appear to produce a greater yield, was that they had only a limited supply of oxide of iron.

Mr. Bell said it did not produce a greater yield.

Mr. Snelus continued by remarking, that after the oxide in the fettling had been taken up by the silica they got a highly silicious slag, and must oxidise more iron—waste indeed more iron—in the furnace to combine with the silica from the remaining silicon in the metal, whereas, in Mr. Danks's furnace, they had an unlimited supply to combine with the oxidised silicon, and so could go on until the whole of the silicon was taken out of the pig; but he did not think it would be found to signify, whether there was one, two, or even five or six per cent. of silicon present. He thought they would find the whole of that silicon would be oxidised with very great ease; for the analysis showed that the silicon went out long before the carbon disappeared, and so long as they had oxide in excess to form a basic slag, silicon would be burnt, and the oxidising could go on until the whole was removed. The fact that silicon could reduce oxide of iron had been fully proved. They could therefore look for a greater yield from a large amount of silicon in the iron, and the difficulty of puddling that iron would be easily overcome now that they had the mechanical puddler.

Mr. Riley was sure every one could confirm the observations which Mr. Bell had made with regard to silicious iron, but his remarks would apply to the old puddling process. They knew very well that if they got a white pig iron containing 2 per cent. of silicon, practically speaking they could not puddle it at all; it would work

dry, and produce a very inferior yield. In the same way they might put it into a refinery and blow it seven or eight hours, and it would not be good metal even then. But he could quite agree with Mr. Snelus that they were working under totally different conditions in a Danks furnace, as compared with those employed in an ordinary puddling furnace. In one case the silicious material was oxidised at the expense of the iron, while in the other case it was at the expense of the oxide of iron, and they got the iron reduced. He knew that all practical men would agree with him when he stated that he was very glad to hear that such was the case, and he should be only too happy to find that it was so, because it was so easy to produce silicious pig iron. Perhaps, he might be allowed to make a few further remarks with regard to silicon and phosphorus. He had made some remarks on the previous day with regard to silicon, and he thought the general opinion amongst ironmakers was that silicon, sulphur, and phosphorus were the three great evils with which they had to contend in iron making, and that the less they had of them the better. Well, he was not disposed to think that it was so, but he thought that with regard to sulphur he should rather put that out of the question altogether, but that they might so use the silicon and the phosphorus that they could be employed advantageously. The only fault was that they had them sometimes in too great a quantity, and they hardly knew how to deal with them. Let them take a few practical points in confirmation of these views. If anyone would take good white pig iron they would find that that iron contained about 1 per cent. of silicon. If they got a nasty iron, they would know it by its appearance. They could tell pretty well what the pig irons contained by their appearance, and when they saw a nasty pig iron that had got a lot of lumps like so many peas in the top of it, which, when struck with the hammer, sounded like a piece of lead, it was bad iron, whereas a good piece of white pig iron would ring almost like a bell. If they puddled that iron which had that nasty face, what would be the result? A puddler could scrape it up together in a very short time—work the heat out quickly—and from it they would get a very inferior quality of puddled bar. That pig, he would say, contained less than from two-tenths to three-tenths of silicon, whereas he believed, if they had more silicon in it, it would delay the time taken in the puddling, and they would thus be able to

puddle the iron longer, and consequently get a better result. When the Bessemer process was first tried at Dowlais in the year 1856, they started with it on their white pig iron, and blew that iron to such an extent that all the silicon was dispersed, and probably all of the carbon, or nearly all. Well, the consequence was that they could do nothing with the iron. It went all to pieces under the squeezers. They could not puddle it at all, whereas if there had been some silicon in it, or rather, more silicon in it, he believed they would have been able to do so. With regard to phosphorus, they knew that in steel it was, as a rule, very detrimental, but if they took the best Swedish pig iron and puddled it, they could get a red short iron, and they could not make anything else from it. Again, take another kind—carbonised wrought iron—melted by Parry's Patent. Puddle that, and they would get a splendid iron, but it would be red short. He believed a little phosphorus would quite cure that, and they would then get a good iron by mixing with it some Middlesbrough pig, or some other pig containing phosphorus. With regard to sulphur, he had seen some statements that sulphur strengthened pig iron in this operation. His hearers knew, however, that if they took grey iron, say No. 1 Bessemer, it would be weak pig, but they could make it stronger by adding sulphur and converting it into No. 3 or 4. The sulphur would have that effect, but it was a very roundabout way of getting at it, because sufficient of the common pig, or white iron, could always be made to mix with it and to reduce the quality. There was a point he had touched upon on the previous day with regard to silicon. He quite agreed with Mr. Snelus, and in fact no one could gainsay the point, that it practically reduced the tensile strength of Bessemer steel. His attention had been directed to steel castings. He had been very carefully analysing them, and as it was an important matter he might be allowed to refer to it. He particularly alluded to some steel castings and steel wheels that had gone abroad, which were broken. They were submitted to him, and the result he had arrived at was that the proportion of carbon in them was too high—about 1·3 per cent. He had made a further examination, and analysed the ingots of steel from which these castings were said to be cast, and he found that they contained about fourth-tenths per cent. of carbon. It was thus quite evident that too large a quantity of the spiegeleisen was put with

the puddled steel. It was puddled crucible steel which was used to make the solid castings. From what had fallen from Mr. Bessemer on former occasions, he knew that he had always held that silicon made castings sound, but what he (Mr. R.) proposed to do was simply to add a little silicious iron to the steel that was being used for the purpose of castings, to see if they could not by that means get solid castings, which was the practical difficulty. Assuming (which he was not ready to admit), that it decreased the strength of the steel to a small degree, it was then a question whether that was not more than balanced by getting a very much sounder casting. Of course, he merely suggested these points. They ought to be worked out practically, and that had been the direction in which he had been working for some time past. It was very easy to make silicious iron. They could get the composition of it and make their steel combine, and he thought it was of sufficient importance for practical men to try the effect of it. Everyone would agree with him that it was a most surprising thing that they could get a piece of workable steel with over 2 per cent. of silicon in it, and workable steel that had turned the skin from steel castings, the tool not breaking but being turned up, showing that the steel was tough. He had also made small buttons of steel, containing about 3 or 4 per cent. of silicon, which had been perfectly malleable, and would flatten under the hammer before they would break. He was very much astonished at these results, and thought they were worthy of some attention, and, therefore, he hoped they might be practically applied to the manufacture of steel.

Mr. Forbes said there was one point in connection with Mr. Danks's furnace which he should like to make a few remarks upon, one upon which much stress had been laid, and that was that by the action of the molten iron on the fettling, they increased the amount of iron or yield obtained. Now, it seemed to him, although he was perfectly satisfied himself as regarded the merits of the matter—that it was a step in the wrong direction to seek to destroy the fettling for the sake of getting a little additional iron. He considered they ought to go the other way, and strive to make the fettling as unattackable and refractory as possible. Rather than use an oxide which was easily reduced, he would prefer—notwithstanding the fact mentioned with reference to titanium—employing

an ore which was not so easily reducible, in order that the fettling should stand so much the longer. It came to this, that if they took the reducing action as a basis, they might as well commence at once by putting in iron and reducing it, going on in that way without, in fact, bringing it to cast iron at all. And for that reason, he would like to hear the opinions of the Commissioners as to whether it would not be better to make the action as neutral as possible, which he had no doubt could be done in Mr. Danks's furnace, so that there should not be any more reducing action than was absolutely necessary to produce the exact amount of iron which ought to be got, and not to act on the fettling so as to obtain more.

Mr. Snelus thought the question which Mr. Forbes had put was not a very difficult one to answer. It was, as he understood it, whether it was advisable to get an increased yield in puddled bar from the fettling itself, or whether it was better to use such a fettling, if possible, as would not produce metallic iron, and would therefore last longer as fettling. Now, his own opinion was, that it was far better to have a fettling which would give up as much metallic iron in the puddling furnace as possible, because he considered that if they could get a hundredweight or two of puddled bar, worth 7s. the hundredweight, out of the fettling, it was much cheaper to produce that hundredweight or two out of the puddling furnace than to make it from the same ore in the blast furnace, because in that way, they had first to make it into pig iron and then to waste it in the puddling furnace, in order simply to retain the lining. They should bear in mind that the lining of Mr. Danks's furnace was put in with the greatest ease; in fact, one hour always sufficed to fettle the furnace, after a heavy day's work, or, at least they found it so in their experiments at Cincinnati. After a man had made his eight heats in the day, one hour was quite sufficient to do all the fettling that was required. Of course, it was only a question of figures, and they could easily see whether the value of the extra puddled bar would sufficiently compensate for the extra cost of the fettling. For his own part, he believed the puddled bar was very much more valuable than the fettling, and that it was more economical to get the iron out of the fettling in the furnace than to go the roundabout way of getting it out of the blast furnace, by first reducing the ore to the state of an alloy.

Mr. Forbes wished, in answer to Mr. Snelus, to go one step further. They had got a very satisfactory answer from him, and one which, in fact, led to the supposition that ultimately a furnace of that character might be even adapted to the direct production of puddled iron without the intervention of the blast furnace at all. He would only ask Mr. Snelus—who had had so much experience in the working of this furnace—whether he thought that there was any reasonable ground for anticipating that such might be the case, and whether he considered it likely ever to be successfully done in that way, without first employing the blast furnace.

Mr. Snelus was afraid the case which Mr. Forbes had put could not be quite carried out to the extent which he supposed. They must, of course, bear in mind that in the reduction of the oxide of iron by the Danks's furnace, or by any puddling process where oxidation was obtained from the solid oxide, they had both the carbon and the silicon (which they used as reducing agents) in a fluid condition. Now, he did not think it would be very easy to get carbon and silicon into that furnace in a fluid condition, except as an alloy with metallic iron. If it were possible, then, it was probable that they might get a direct process of reducing oxide of iron, but, as it seemed to him, it was almost impossible to do that except to a limited extent, therefore they could not go very far in that direction—in fact, Mr. Danks had gone nearly to the full extent. They might make a more silicious metal, and thus get an extra amount of the fettling reduced, but his own experience taught him that it was not possible to put more than 5 per cent. of carbon into pig iron, although they all knew a much larger quantity of silicon could be put in. Mr. Riley had said that he put as much as twenty-two and a half per cent. of silicon into the iron, and in that direction he thought it was possible to go a little further than they had hitherto done, but there should be some limit to it.

Mr. Riley rose to correct a mistake which Mr. Snelus had made. The experiment to which he had referred was artificially made, and he did not think they would get the same result in practice to anything like this extent. His object was to go to the greatest extent he could, but he might say that practically silicon had been put into iron in the blast furnace to the extent of 18 per cent. That was done at Towlaw by Mr. Charles Attwood. He could hardly

recall the circumstances under which it was made, but there was that amount of silicon in the pig iron, and as much as 8 per cent. of iron was obtained from some very silicious iron ores used at some of the Wigan iron works in Lancashire. At Dowlais, pig iron containing 7 per cent. of silicon from some very poor black band was produced. The conditions were pretty well known under which silicon could be made to go into pig iron. He thought he could make silicious pig iron up to 7 or 8 per cent. of silicon without much difficulty. As regarded making wrought iron direct from the ore, he believed there was certainly very little hope of that being carried out practically or profitably. He thought no one could conceive any method more simple than the present process of throwing the materials into the blast furnace for the purpose of reducing them, and he was sure that all improvements in iron should commence with the pig iron. They could make it in any quantity, and they ought to start there. He could not conceive any other process of making iron cheaper. With regard to steel, there was a great difficulty in getting a first-class tool steel, and he was disposed to think that with a purer ore and materials generally, it would be possible to make a very much higher class of steel for cutting tools, punches, and such like articles; because it was not a question of price, if tools could be got that would stand and would cut, the price was a secondary object. He had made experiments on this subject, and those experiments led him to this conclusion. He knew this to be a complaint of engineers generally; Mr. Ramsbottom, of Crewe, had told him they had found it impossible to get a first-class tool steel, although they had offered to pay any price for it, and there they were actually using up some old steel slide bars, which were made by the London and North Western Railway Company when it was first started, and they could get no steel like it.

Mr. I. Lowthian Bell thought that a certain amount of disrespect had been shown with regard to the blast furnace, in speaking of it as a roundabout way of doing the work which was performed by it. There was no doubt that they combined the iron with carbon or silicon in the smelting process, which had subsequently to be dispersed; but they must remember that the blast furnace at the same time got rid of earthy impurities generally found associated with iron ores. He, therefore, quite agreed with Mr. Riley that

although it might be a roundabout way in the first instance, they could not conceive any means so simple for getting rid of a large amount of extraneous matter as blast furnaces. There was another observation of Mr. Riley's to which he would take exception. Mr. Riley seemed to think that they had two enemies to deal with in iron—hot shortness and cold shortness—and that if they had a given quantity of cold shortness they had only to add a corresponding extent of hot shortness to neutralise the effect of the former, but he believed his friends would admit both these detrimental qualities were sometimes met with in the same iron.

Mr. Riley thought he did not make such remark, at least he did not intend to convey that meaning certainly, because it was a very well-known fact that they did get iron both ways, and nothing would correct them.

Mr. Cowper said Mr. Danks's way of using oxide of iron in the puddling process had been described, but, as he understood one speaker, it was thought to be a pity to use such a large quantity of oxide of iron in the furnace, for the purpose of bringing round cast iron into wrought iron, by the union of the oxygen and carbon. If he heard Mr. Forbes correctly, he suggested the possibility of using ore in the puddling furnace instead of cast iron, and that he rather objected to the use of a large quantity of oxide of iron for the purpose of reducing cast iron into wrought iron. Now, he did not see at all how that action could take place in the puddling furnace, because the puddling furnace *per se* had little or no power to reduce cast iron into wrought iron. The process that went on in the puddling furnace was due to the combination of the oxygen of the ore with the carbon of the cast iron, and when the ore and the cast iron were brought together, and were rabbled, or turned round in the rotating furnace, then the puddling process proper ensued; but if the ore was put in with the idea of its being reduced into wrought iron, he would ask how it was to be done. They knew that Mr. Siemens was making excellent steel from ore, and probably before long he would make excellent iron from ore also; but that was a totally different process, and in another direction altogether. He would like to know this, if he correctly understood the suggestion that Mr. Forbes intended to convey in reference to using ore instead of cast iron. He conceived that the oxide of iron put into the furnace as "fettling" on Mr. Danks's plan, was put

in very cheaply, and answered the purpose very well. What Mr. Danks required was rather more "fettling" than the quantity of cinder which he made, therefore, that showed that his furnace would do one very good thing, which was, whilst it made an improved quality, it also brought in an improved quantity of iron out of the fettling. He thought that was a very meritorious way of doing two things at once. They got a larger yield of wrought iron from the reduction of the ore, whilst they conducted, at the same time, the ordinary process of puddling. In this way, there was more wrought iron coming out than cast iron went in, and he had yet to learn that this was a fault.

Mr. Forbes was afraid that Mr. Cowper had rather misunderstood him. The question which he had put to Mr. Snelus was to ascertain from him—as far as the experiments had gone—whether it showed that it was more economical to reduce that iron at the expense of the fettling—that was to say, at the expense of the iron—than it would be (as they had perfect command in the Danks's furnace over the reducing, or oxidizing action) merely to get out the exact quantity of iron without reducing it. That was the question which he had proposed. He did not for a moment believe that the puddling furnace would be made into a direct furnace for producing finished iron. He only said that it was a step in that direction, but it was a question whether, in working Mr. Danks's furnace, it would not be better to do away with the reducing action, because he supposed, and he believed so still, that the excess of iron which was reduced would be rather expensive, the ore which they employed for fettling being much higher in price, independent of the expense of fettling, and, therefore, he thought they would get as good a result, economically, from the furnace, by using the most refractory fettling and making the flame as nearly as possible neutral. This Mr. Danks could do, because he had the advantage in using the blast, that he could prevent any external oxidizing action, a result which they could not attain in the ordinary furnace.

Mr. Cowper feared he did not quite make himself understood. He rather maintained that it was not at the expense of the furnace or apparatus that this reduction took place, but at the expense of much oxide, put in as "fettling," and which, as Mr. Snelus had said, was put in very cheaply, and very easily.

Mr. J. A. Jones said the question to be considered was how long

the fettling ought to last. In his opinion, it ought to remain good sufficiently long to take up the silicon, the carbon, and the phosphorus in the metal, and if they could produce good iron by the elimination of these substances, then the fettiing should last so long. When these were taken out, it should become refractory, and not before. The gain in metal by reduction of the fettling could only go on whilst any of the above three elements remained in the pig iron. If the fettling were melted out without being reduced it was clearly waste. He thought Mr. Forbes was labouring under a misapprehension altogether, when he said that the lining of the puddling furnace should be refractory. He considered that Mr. Menelaus had not made his furnace a success, simply because he did not determine how long his fettling ought to last; and if the fettling was, as Mr. Forbes suggested, refractory in a rotary puddling furnace—or even in any other puddling furnace, a piece of Cleveland pig iron would be utterly useless—it would be so filled with phosphorus—so cold short, and so brittle, that in the market it would be unsaleable, or nearly so, and it was because they had an oxide in the furnace which was capable of taking up the phosphorus, and converting it into phosphoric acid, that they were able to make the metal into a malleable article. He thought there was nothing more satisfactory in the Danks's machine than the beautiful manner in which it utilized the fettling that was put in.

Mr. Edward Williams said that as they had got away from the region of chemistry back into that of practical puddling, he should be glad if they would hear a remark or two from him. He thought the whole point of what Mr. Forbes said had been lost sight of. He quite agreed with the view he had taken, and considered it was highly desirable, and advantageous to find a refractory material for lining the puddling furnace, one that would not wear out at all. He did not mean by that, that they were not to have the necessary oxides of iron in the furnace, but he believed that they could be very much more cheaply put in—charged in the way that the iron was charged, so as to produce oxides, rather than by being put in, in the present expensive way of lining the furnace, for the purpose of being wasted away very considerably by each heat. Refractory metallic ore would, he thought, make an excellent lining for the Danks furnace, and if the facts proved to

be as they were there stated, they would not find any difficulty whatever in obtaining the necessary oxides for charging with the heats in the proportions necessary. Now, they at Middlesbrough had a very high respect for their produce. They thought that in most things their iron was of the very best quality possible, but in spite of all the good feeling they had for it, they had been obliged to admit that it had one defect, and that was, that it contained from 1 to $1\frac{1}{4}$ per cent. of phosphorus. That they had always looked upon as a thing to be deplored, and very much attention had been given to the question—how to eliminate that phosphorus, but up to the present time they had not succeeded, and if the statements made at that meeting were correct, they had been working altogether in the wrong direction, because he found from these statements that every 1 per cent. of phosphorus was equal to 3 per cent of wrought iron, *ergo*, the greater the amount of phosphorus the better it was for them. The same remark applied to silicon and to carbon, and really it now turned out that the things they had been calling imperfections, in the past, instead of being so, were going to be, as it appeared to him, items of very great profit. Not being a chemist, he failed to see why, if it really was the case, the carbon in the pig iron in one operation converted oxide of iron into wrought iron, they could not put into the furnace carbon in some cheaper form, say, for instance, in the form of coal alone; at all events, why, in some form or other, the same operation should not go on by charging carbon and oxide of iron without the intervention of pig iron at all. How far it was possible to do that, the chemists should determine, but to him that seemed to set them upon a path which would ultimately lead to the abolition of the blast furnace altogether. He did not know what Mr. Bell would say to that, but he did not think he would consent to have the blast furnace swept out of existence without some effort being made to save it. But the admirable paper of Mr. Snelus led him to the conclusion that the putting of carbon into the puddling furnace, mixed with pig iron, was a roundabout, costly, and needless way of doing it. There was one clause in Mr. Snelus's paper which he would ask him to explain. He said "It is well-known that phosphorus possesses the power of reducing many of the metals from their salts, but I am not aware that it has been proved to have this power upon oxide of iron.

However, from the preceding experiment upon silicon, and the known avidity of phosphorus for oxygen, I am inclined to think that it has this power, but I have not yet made the direct experiment." Now, if phosphorus had that great avidity for oxygen, how did it happen that there was no getting rid of it by the Bessemer process? It might be that they were in that respect as they were in their old notions of puddling, but up to that time they looked upon phosphorus in Bessemer pig as their great enemy, and certain it was that whenever phosphorus was to be found in the pig iron on its going into the furnace, they saw in the steel when it came out that there was no appreciable quantity of it got out during the blow. That being so, he did not quite understand how it could be possible that phosphorus had this great avidity for oxygen. He thought the papers they had had from the Commissioners, the opinion they had had from Mr. Danks, and from other people, as to the Danks furnace, gave them the greatest reason to hope that not only would their knowledge of iron-making be very much improved, but that the labour of puddling would be very nearly or entirely got rid of, and that they would then have for the conversion of pig iron into wrought iron a class of men who would be ready and glad to go to the occupation of puddling, which would be a comparatively light one, instead of as at present, a most unwilling class of people who would not puddle at all if they could help it.

Mr. Snelus said that he did not intend to convey the impression that Mr. Williams had put upon the matter. No one could be more satisfied than himself of the injurious effects of phosphorus upon steel, and of the fact that it did not go out in the Bessemer process. He had his own opinion about the reasons why it did not go out in the Bessemer process, which, however, he was not quite at liberty to make known at the present time, because he was working in that direction, and had some hopes of surmounting the difficulty. That it did not go out in the Bessemer process they were quite certain, but that it was very much reduced in the other process they were also certain. Therefore, there would be some reason why they did not then agree, and, as he was working in that direction, he might be able, bye-and-bye, to tell them why it was; but he had not gone far enough with the experiments. With respect to the point, upon which Mr. Williams entirely misunder-

stood him, that the cheapest way of putting carbon into the furnace was to put it in in the form of pig iron, he could only say, that was not exactly what he had stated. What he said was, that the carbon in the pig iron would, of course, produce a corresponding quantity of wrought iron, but they could put carbon into the puddling furnace much cheaper than by putting it in in the form of pig iron. But there was this difference—when they put carbon into the furnace in the form of alloy with pig iron, they got it there in a fluid condition, and he maintained that they could not do that by any other known means. There was not even a cheap alloy of carbon with any other metal that was known, and therefore as it was the only possible way, it would certainly be the cheapest. Then again, with reference to the use of a more refractory material, they must bear this in mind, that supposing they could line the vessel with a perfectly refractory material, which did not waste away at all, and that the oxygen was to be supplied by oxide of iron, thrown in with the pig iron, this would be lighter than the metallic alloy, and would only float on the surface, and the reason why a man had to rabble away so hard was to poke this oxide underneath the surface; whereas, Danks's furnace, being lined with an oxide, gave three times the surface action that they would have if they threw it on the surface, therefore it did the work three times as fast. Then again, suppose it were possible to put in a refractory lining, which did not give metallic iron, but which contained the oxide of iron in such a form that it was only reduced to a state of protoxide, instead of to the metallic state. He thought such a material would not be good, because in that case they would get only protoxide of iron, which would be useless, and would go away as slag. They might not lose so much as in the other case, but they would get a useless product in the place of a very useful one.

Mr. Danks said he thought the question of puddling had been treated in a very scientific manner by some of those who had entered into the discussion. As to the chemical part of it he did not intend to make any remarks, but in regard to the practical part of puddling, what had been done in his furnace, and what it was expected to do—all of which had been brought before the Institute in a very straightforward and intelligent manner, and had been made much more clear perhaps than he could make it—he would

like to make a few remarks. They spoke about phosphorus and silicon being advantageous in pig metal. He frankly confessed that if that had been told to him five years ago, he would have said it was impossible; but his experience had been such as to alter his opinion, for he had dealt very largely with iron containing as much as 2 per cent. of phosphorus and a very large amount of silicon, and he had found those things in his furnace to be very advantageous. Now, he might not be able to explain the scientific reasons for that, but it was to him an undoubted fact. They would take an instance of some iron made at Chattanooga, Tenessee, at the Roane Iron Works, which was also very silicious. He could not tell the exact amount of silicon in it, but by puddling it in any common furnace, they were able to produce only three to four heats a day, and that at a sacrifice in yield of from 15 to 20 per cent. They used a very large quantity of oxide of iron for lining the furnace, and it produced such cold short iron, that they might take a bar of it $3\frac{1}{2}''$ broad by $\frac{3}{4}''$ thick, drop it down, and it would break into several pieces. They might puddle that in his furnace—which in America they did regularly—and they would find that the phosphorus was removed, and also the silicon, and that it made the finest brand of tough fibrous iron to be found in America. Instead of losing 15 to 20 per cent., there was an actual gain of from 6 to 10 per cent. in the puddling. Now, they all knew that the iron did not grow there. They knew very well that there must be a reducing agent at work that would reduce the oxygen that was in the lining or fettling of the furnace; for it ought to be borne in mind that the puddling furnace was not simply a discharger of carbon. It was, essentially, a refining process, and the removal of carbon was not all that they had to do in this case. They knew that blast furnaces did not make pure pig iron, because it had got mixed with silica and sulphur, and sometimes with other impurities, which must be removed if they were to produce a good pig iron. He had never found anything in his experience equal to a pure oxide of iron for the removal of those impurities, either in the common puddling furnace, or in the revolving puddling furnace. Now, as he said before, he could not tell why. He could not give the chemical reason for it, but he knew that it was a fact. Again, in regard to puddling ore direct, he had had some experience in this matter, having been an experimenter all his life—in a small way it was true

—and 27 years ago he was puddling ore direct—not in the revolving machine—and he had succeeded in making some iron, as good as any that could be made. He had tried it also in the revolving puddling furnace with some of the richest American oxides of iron. They had the analysis of an ore which was to be found in America—the Iron Mountain ore of Missouri—which showed that it contained from $\frac{3}{4}$ to 1 per cent. of silica. They had some containing as much as 5 per cent. of silica. Now, he had succeeded in making very good iron direct, in the puddling furnace from that ore, but the difficulty lay where Mr. Snelus had said. The difficulty of using carbon as a reducing agent in the puddling furnace was because they could not bring particle into contact with particle, and not only so, but even if they could bring particle into contact with particle, it would require so much time, that when they had done it, it would be always unprofitable. He had charged, for instance, ore and carbon, or salt, or whatever he required to convert into blast or slag—letting it remain in the furnace all night at a slow heat, and he then invariably found that the surface of it for a depth of from 2 to 3 inches was converted into malleable iron. He put that into the rotary furnace, and kept it at a low temperature for three or four hours, and when he raised the temperature, the carbon not combining, he could not remove the oxygen in that way. The main difficulty in the puddling was the time required to produce the combining of the carbon with the oxygen, but as a rule, that system could never be applied very effectually. As Mr. Bell had stated, there was a large amount of silica and earthy matter to be removed. That was just what they found, and he thought it never could be done satisfactorily in the puddling furnace, indeed, he was quite certain of that. In regard to puddling direct from the ore, he was quite satisfied with his experience of it. Next, as to the use of silicon and phosphorus, five years ago, he should not have considered them suitable for his furnace, and, therefore, he did not wonder that some gentlemen were doing so now, but he was now convinced that they were really serviceable elements, that was, when used in the Danks Puddling Furnace.

Mr. Spencer had only a few observations to make, for the purpose of getting from some of those present information that would clear a difficulty under which he was labouring. He agreed with Mr. Snelus and Mr. Danks, that a lining consisting of

a rich oxide of iron was required to puddle efficiently, and to some extent he concurred also in the views expressed by Mr. Williams and Mr. Forbes. If they were putting the lining in simply to waste away by reducing itself very quickly, that would be done at some cost, and this was the point that he wanted to get at more clearly. What was the cost of the excessive wasting away or fusion of lining? They would take figures to illustrate it. He would suppose that the lining costs 40s. per ton, and that it was reduced 50 per cent. It was clear it took two tons of such lining to make one ton of iron, and the iron thus produced would cost 80s. per ton. Thus it appeared to him that there was no more economy in 40s. lining than in using pig iron which was worth 80s. per ton. There was no benefit that he could see in using an excessive quantity of the lining, and he would like to know from any one present where the economy they talked of in using this thick lining lay, because if it was rich in iron, it must be put in at some cost as a matter of course, and he again would enquire the cost of this rich oxide. He had been experimenting with an oxide, and he knew that it was essential in the revolving furnace that a rich oxide of iron should be used for lining, but he would be very sorry indeed to see his lining go away very rapidly. He thought the best point was the medium, where they could produce a ton for a ton, for if they produced a ton out of 18 cwt., it was done at the cost of an excessive quantity of lining, which must be replaced at an expense of time and labour, and of course with original cost. If any one could give him an explanation as to the economy of that, he would be glad.

Mr. J. A. Jones thought it was as well to make the thing quite plain—Mr. Spencer was labouring under a misapprehension. So far as the Commissioners' experiments had gone in America, if they looked at the tabulated statements they would see that the fettling was not wasted *per se*, as it did not come out as it went in, but that the fettling was really utilized and converted into iron. The Danks machine could only utilize the fettling so far as there was carbon, silicon, and phosphorus in the pig iron to oxidize, and if it was melted out after that was done, it was pure waste, and the bulk of it by the common process was pure waste, but in the Danks process a great deal of it was saved. It ought not to be absolutely refractory. It would only be refractory after these three elements

had been taken out. They understood how iron and steel could be made direct from a very rich oxide of iron. Take the Iron Mountain ore of Missouri, for instance, which contained from 60 to 70 per cent. of metallic iron, and in which no phosphorus and no sulphur really existed. By putting it into a retort or furnace, and allowing it in a powdered state to take up at a slow heat a layer of carbon or charcoal, and then if the sponge produced was melted in a Siemens furnace, it was easy to see how steel or wrought iron could be made direct with the Iron Mountain ore of Missouri, not with Cleveland, Welsh, or Scotch ore, but only with a very first-class ore.

Mr. Danks, thought that, in regard to cost, the actions and reactions of these oxides in the Danks Puddling Furnace had been sufficiently discusssd. He might just observe, however, that if they had a pure oxide of iron in that furnace, it was next to impossible to melt it at any temperature that they could get; but in practice there was found to be no such thing as a pure oxide of iron, therefore, they had to deal practically with such as could be secured. The purest oxide of iron that they could get had been named. This was the Iron Mountain ore of Missouri, which contained from three to four per cent. of silica. The silica in the ore determined its value as a lining for the furnace. It was well known that an oxide of iron was exceedingly refractory, and could not be melted *per se* in puddling furnaces, but as he had already stated, there was no such thing in practice as pure oxide of iron. But if they combined an oxide of iron, he would take, for instance, the Iron Mountain ore, and place that in the puddling furnace, they might succeed in getting it into something like a pasty form, but if they introduced twenty per cent. of silica to that, it would become much more liquid at even a much lower temperature. This would serve to illustrate the value of this oxide as a lining, because it required a much higher temperature to melt the lining of the furnace than to melt the ore that was being puddled; and after these conditions were complied with, that was, after a certain amount of oxide of iron in oxidising the silicon and the phosphorus that was in the iron had been taken up, there was no more that could melt, unless a higher temperature was attained, which, of course, would be good for the iron, and would also be more profitable to the manufacturer. In this way there could be no waste. They had the best possible

proof of this, because, in the Danks Furnace, they first refined the iron, oxidizing the impurities to the best of their ability, before they "balled," and while the furnace was at a low temperature they drew those impurities off, so that they could not contaminate the iron by further contact when the temperature was raised. Therefore, they had in the furnace nothing but pure oxide of iron, and it gave off, Mr. Snelus had shown, nearly all the carbon that it had when first put in, for it seemed to give up these impurities—phosphorus and silicon—before it parted with its carbon. He would describe what they should do with what they had now got. They raised the temperature of the furnace and set the machine in motion, and it then seemed that every portion of it was brought into intimate contact with the lining or fettling, and the reducing action was only able to go on so long as the "blow" reduced that fettling, and the wasting could not proceed beyond. That was the way in which they worked the machine and removed the oxygen, while the iron was left behind. The remarks that he wished to make more particularly referred to the cost. He did not know what the cost of the plant would be in England, but he could tell what it would cost in America. He had sold the furnaces in America at 1,500 dollars currency, but to put one of them in a condition ready to start work—ready to charge a heat in—cost 1,800 to 1,900 dollars, according to locality. That sum could very easily be reduced to English money. He dissented from some of Mr. Jones's remarks—not that that gentleman had done any intended injustice. He did not agree with him in this particular respect. He had treated the subject fairly in a commercial point of view, as far as he had gone, but he did not go quite far enough. In regard to utilizing the waste from this iron ore, he would assert that the furnace should have credit for "puddled bar," instead of "pig metal." That made a very considerable difference, because it cost something to convert pig metal into puddled bar. He would take a familiar example to illustrate this. They started with one ton of pig metal, and added to that the cost of coal, labour, iron ore, fettling, and all the materials that were necessary to reduce that to puddled bar, and what did they obtain? They should not forget that they got about 18½ cwt. of puddled bar from it, and it was very easy to see when they worked it out. In estimating the value of the puddled bar, if they put it at 7s. a

hundredweight, they would see what it was worth. Then with the very same material, using an equal amount of labour, the same quantity of iron ore, and the same of coal, and it produced 22½ cwt. in the Danks furnace, instead of 18½ as in the other. Put at the lowest estimate, the one at 18½ and the other at 22 cwt., and there would still be a difference in his favour of 3½ cwt. What was that quantity worth, taking 7s. a cwt. as the price? That would give 24s. 6d., and Mr. Jones made the saving appear to be only 15s. or 16s. per ton.—Mr. J. A. Jones: Ten shillings and eightpence (10s. 8d.).—Mr. Danks, continuing, said that showed in one item alone—the saving of the yield—that there was a clear gain of over £1 a ton, putting it at a very low figure.

A Member reminded him that there was the value of the ore to be considered.

Mr. Danks said there seemed to be a rather general impression that the cost of the fettling in his furnace was so large that it absorbed a great part of this gain. This was not the case in America. What it might be in England he was not prepared to say, but he did not think it would be more in this country than in America. The average consumption was 6 cwts. to the ton of bar produced, sometimes it was as low as 3 cwts., but he thought he might state with the greatest exactitude that it did not exceed an average of 5½ cwts. to the ton of iron produced. That was quite as low as the average in the common puddling furnace, but the difference was this, that in the common puddling furnace they not only wasted the whole of that fettling, but some of the iron also, while he got all the iron, or at least the greatest part, out of it. He believed that from the time they commenced to use that furnace to the present, for every ton of iron ore that was used in it, an average of 50 per cent. of iron had been produced, a quantity which was entirely lost in the common puddling furnace; there was, therefore, a great gain in the value of the iron ore, because it had been changed from iron ore into puddled bar, and he would ask that the furnace should have credit for puddled bar instead of for iron ore.

Mr. J. A. Jones thought Mr. Danks had misunderstood his estimate. If he referred to the detailed estimate of the cost in production, he would see that he took the pig iron at 18 cwts. 2 qrs. 25 lbs. per ton of puddled bar. That was the actual quantity that

had been produced at Cincinnati. He fully agreed with Mr. Danks that he had under-estimated the saving which might be expected from this machine, but he deemed it more prudent to do that than to bear the opposite way. He wished to correct what was said by Mr. Siemens in the remarks he had made at the opening of that day's meeting, because that gentleman had misunderstood what he (the speaker) had said on the previous day as to the Siemens-Martin process. He did not wish to convey the impression that he expected any direct result to be arrived at by the rotary furnace, but what he meant to say was that in Middlesbrough they had had the Siemens-Martin process in operation, and Mr. Samuelson had conducted a series of costly experiments there, with the view of converting Cleveland iron into Siemens-Martin Steel, and in that he utterly and absolutely failed. He was quite unable to use Cleveland pig iron as a bath, nor could he utilize it as wrought iron. He had meant to convey to the meeting, that, if the Danks puddling furnace—by reason of its better oxidizing capacity, as compared with an ordinary puddling furnace—was such that they could put Cleveland pig into it, take out the phosphorus to such an extent as they had heard described, and then tap out the melted product, in a partially converted state, he thought this furnace would supply sufficient heat to do that, because he did not intend to reduce it to such an extent as to require an enormous amount of heat to keep it melted. He desired to take out a little of the carbon—say one-half of the carbon, about three-fourths of the silicon, and, if possible, the whole of the phosphorus, and then to remelt the product in a Siemens hearth. He did not know whether it could be done, but it appeared to him to be an interesting thing to look forward to.

Mr. Siemens said he had certainly misunderstood the remarks made by Mr. Jones on the previous day, perhaps it was because he had not explained them fully. He had understood that Mr. Jones thought it possible that this process of making steel could be carried out in the Danks furnace. If the question was one of puddling Cleveland pig, so as to make it suitable for the Siemens-Martin process, he had not a word to say against it, except that he must see the analysis of the puddled material before he made up his mind as to its merits. If that analysis were shown to him, he would be able to say at once whether the metal was suitable or

not for the Siemens-Martin process, because he knew exactly how much phosphorus and how much sulphur he could do with; and, if, in the first instance, Mr. Samuelson had put clearly to him the question whether he would be able to make steel from Cleveland pig, he (the speaker) would most decidedly have told him that he did not believe he could. He thought it could not be done unless they could show him that they could remove phosphorus to a much greater extent than the ordinary puddling furnace had yet accomplished. With regard to the yield, he agreed entirely with the views which had fallen from Mr. Snelus, and which were in conformity with the chemical reasoning the speaker had advanced in his paper on puddling iron. He had showed on that occasion that they could gain 8 per cent. in puddling Cleveland pig in a theoretically perfect manner, and he felt glad to see that results so near perfection had been realised with the Danks furnace. He accorded with Mr. Danks's view, that it was not at the expense of the fettling ore that they obtained the increase. In the ordinary furnace it happens that, although they had much silicon in the pig metal, a portion of that silicon was burnt off by the direct action of the flame, but in a furnace where there was but little oxidation by flame, very little of the silicon was burnt, and the great bulk of it was oxidized by chemical re-action with the oxides of iron present; but they must have the oxides present, no matter whether they intended to make iron of them or not, and the difference between economical and wasteful puddling was due to whether they retained the iron from these oxides, or whether they wasted it after getting it. In Mr. Danks's furnace, and also in a regenerative gas furnace, if properly conducted and worked, they need not waste the iron, and they could then get at least "weight for weight."

Mr. Snelus wished to refer to some remarks made in his paper, more especially as many of the gentlemen present could not be supplied with a copy of it. In order to test the question as to whether steel could be made from Cleveland iron by the process suggested by Mr. Jones, he (the speaker) had taken very careful samples during the process, in order to see how far the phosphorus was eliminated at certain stages of the operation,—in fact, that was the main object of his investigation. He considered that it was one of the most important problems arising out of the process. They would see that he had stated that, in order to solve the question as to

whether steel could be made from Cleveland iron, he had taken 5 lbs. 2 ozs. of Cleveland puddled bar, which contained a little over four per cent. of phosphorus. He had assumed that some of that was there as slag, he did not know exactly how much, possibly it might all have been there as such; if so, when the product was melted, they might have expected the phosphorus to remain in the slag, and not go into the melted iron. The result was that he got a loss of 4·8 per cent. only, but the product on analysis showed ·424 per cent. of phosphorus, which was of course sufficient to be quite fatal to the making of good steel. Then again, as another experiment, bearing perhaps more directly upon the question, he took about two parts of the puddled bar and melted it with one part of best Bessemer pig iron, but the result was that the mixture still contained ·269 of phosphorus. There was, of course, a corresponding reduction due to the pure pig iron. But the result was that it was still too high in phosphorus, and if they followed the analysis through, they would find, as far as his experiments and analysis had themselves gone, that at no stage had they got phosphorus reduced to a sufficiently low limit to enable good steel to be made, either from the metal in a fluid state, or on becoming pasty, or when removed from the furnace. He certainly had hoped, with Mr. Jones, that the result would have been otherwise. Still, even though the experiments thus far had not been favourable, he was inclined to think that it would be possible to reduce the phosphorus sufficiently low by-and-bye, but it required a good deal more work. The fact was, that up to that time that point had not been reached. There was a fact which he would attempt to clear up with respect to the wasting of the lining, he referred more especially to the wasting of the lining from the action of the silicon in the pig iron. If they had a highly silicious pig iron, the silicon, as he had shown, would reduce the oxide of iron and form metallic iron, and thus give so much the greater increase in the yield than in forming silica, which cannot exist as silica *per se* in the furnace. As Mr. Bell had explained, it would take up another portion of oxide of iron, and as far as that went there would be so much waste of the lining. Silica was formed by the oxidation of silicon from the pig, and the lining would have to be somewhat wasted to afford the necessary base to combine with the silica produced, and to that extent, and no more, would the lining be

wasted. He thought the terms that they had been employing were not altogether correct when they spoke of the lining being refractory, instead of being a lining that was easily reduced. A distinction ought to be made between the lining being refractory and its being easily reducible. It was quite possible to have an ore, such as ilmenite, which was refractory but not easily reducible. Several good oxides of iron were sufficiently refractory, and it was quite certain they would melt, he himself had melted them, Dr. Percy had done so, and recorded his experiments, and many others had done likewise, but only at a very high heat. Whatever melted, therefore, was so much waste, and whatever was carried out as silicate of iron was so also, but that portion which simply yielded up oxygen to oxidize the silica of the pig was not waste, but, as he maintained, it was a source of very great profit.

The President remarked that on the previous day the Commissioners (which the Institute had been so happy in selecting from a number of practical men) gave in reports, supplementary to their original one. The first paper, by Mr. Snelus, from beginning to end was a memorial of what a sagacious man, having his attention directed to a specific object, could really carry out. He believed that a more careful digest, of all that came under his notice, could scarcely have been put upon paper. They had had also from Mr. Jones (another of the American Commissioners), a most interesting account of the commercial aspects of the question—one that was no less important in its sphere than the previous communication. Mr. Jones had looked, from the figures produced, with great care into the facts presented to him, and he had given those facts to the meeting in a most clear and concise manner. They had also heard a supplementary report from Mr. Lester—the third American Commissioner—which was a most interesting and useful account of the process itself, detailed in the simplest and clearest manner, showing the mode in which the open or naked furnace began to be lined with temporary lining, its mode of glazing, the mode of putting in the oxides of iron, and the lumps afterwards. That was all so clearly stated, that every one could picture to himself the actual operation as it went on at the works. He was sure the members of the Iron and Steel Institute would congratulate themselves in having fixed upon three men so able to carry out their design, and in sending them to America to report upon the most

interesting and most valuable discovery of Mr. Danks, and he, therefore, proposed a vote of thanks to the American Commissioners.

This was duly carried, after which,

Mr. Hopkins remarked that, since the meeting had commenced, he had been asked by a great number of people whether his firm could work the Danks machine that they had already erected, at Middlesbrough, in order that the members of the Institute might inspect it. He had not intended working it again until they had others in operation and a squeezer ready, because they could not show it properly without the proper means of manipulating the ball. However, he would be quite willing to work it for one or two days. When he had it ready, he would send invitations to all who wished to see it.

The President then called upon Mr. Spencer for his paper.

Before commencing the reading of the paper, Mr. Spencer stated that it simply contained an account of what he had been doing. It was not very elaborate, nor statistical, but only a short general statement. He then read as follows:—

SPENCER'S REVOLVING CONVERTER OR PUDDLING MACHINE.

BY MR. A. SPENCER, WEST HARTLEPOOL.

[*The diagrams illustrating the construction of Mr. Spencer's machine, will be found in Journal, No.* 1., *Part* II., *for February,* 1872.]

In bringing an account of this machine before the members of the Iron and Steel Institute, I may be allowed to remark, that for some years past I have, whenever an opportunity occurred, experimented upon materials for a lining suitable for revolving puddling machines; and in 1868, while engaged under Mr. Edward Williams, at the Middlesbrough Iron Works, I became convinced, from some

trials which I was encouraged to make, that "best tap" was the most suitable for such purpose, if it only could be effectually secured to the revolving chamber. From the fact that it could be reduced to the liquid state, the casting it on to plates dovetailed, or any similar fastening, naturally suggested itself.

In 1870, while occupying my present position as manager to Messrs. Thomas Richardson and Sons, at their West Hartlepool Iron Works, preparations were made for practically testing my ideas and observations.

Having now called attention to the most imporant part, perhaps it will be well to describe the machine itself, and afterwards revert to the mode of securing the lining.

As it was only at the last moment that any intention was formed of bringing the matter before this meeting, sufficient time was not allowed to get up drawings on a large scale, but the furnace has been already described and illustrated in the JOURNAL of the Institute, No. 2, Vol. 1.—1872; and I shall be very glad to give fuller explanation to any of the members who may express such a desire.

Excepting the revolving chamber, there is nothing peculiar about the other parts; so we may at once dismiss the grate and the stack by saying they are of the common construction, excepting that they are larger, although not larger proportionally to the work done, than those in use for ordinary puddling furnaces.

The revolving chamber, then, is of the rhomboidal form, supported at the ends by large discs at right angles to the axis upon which it is made to revolve. The transverse section is square; longitudinally, two of the sides are parallel to the axis of rotation; and the other two sides, although parallel to each other, are pitched slightly diagonal; this diagonal throw is intended to give to the charge a motion from bridge to flue and *vice versa*. By the square form and diagonal sides, the iron is made to travel over the whole surface in a very effectual manner, even if the speed of rotation be only one to two revolutions per minute, not only are the flat sides found the best for thoroughly agitating the iron, but for allowing the lining to be equally distributed upon the four sides, thus securing a uniformally smooth surface throughout the interior, which can be easily fettled with molten cinder or "tap." Where the chamber is connected to the furnace grate and to the stack, loose rings are made to butt against

it, allowing it to freely rotate, and very simply securing the joint; the rings are kept well up to their place by levers and balance weights.

Having now, I trust, made clear the general form, I will describe the method of applying the lining. In the first place, the four sides, instead of being formed of plates as at first, are now made up of open-sided "troughs," which reach from disc to disc. Each trough is filled with molten tap, afterwards placed in position. The ends are made up of tap bricks, cast into moulds of the required form, and the whole cemented together by molten "tap." It will now be seen that the chamber consists of two discs connected together by a rectangular box, the sides of the box consisting of troughs open to the outside, each trough containing its quantity of fettling. Further particulars would be tedious, and perhaps confusing. I may, however, mention that the door for discharging the balls is on one of the sides, and near the flue end.

The charge in the existing machine is about 10 cwt. of molten iron, and is poured in at the flue end, or through a small hole in one of the sides. The machine is then made to revolve slowly for about five minutes when the boil commences; the boil lasting about ten minutes, the coming to nature and balling occupies another ten minutes. The door is then opened and the balls withdrawn by means of long tongs, placed on the bogie, taken to the hammer, and immediately rolled off into bars of the required sizes.

With the first machine only about 5 cwts. could be conveniently puddled, and occupied about fifty minutes; thus the present machine has saved half the time and more than doubled the production. The largest production from one heat has been 1,430 lbs. or 12cwt. 3qrs. 2lbs. The shortest time for a single heat has been 13 minutes.

The quality is beyond all question, having been proved by working, by fracture, and by analysis. The metal used has been Cleveland of various mixtures down to Cleveland cinder pig.

A machine is now being constructed to convert one ton per heat, but I have no doubt ultimately 5 tons will be easily converted, for if we can maintain a division of the mass the process will be very simple.

The following are a few figures giving the results of seven heats worked in the furnace:—

Molten Iron charged into Converter. lbs.	Production. lbs.	
535	579	
870	870	
1,045	1,057	slight leakage.
962	944	do.
468	458	
795	766	
783	784	

The few sample heats given were carefully weighed on a small platform machine, and the result shows no loss, in consequence, no doubt, of the richness of the fettling. The number of balls is not given, but would be as usual dependent upon the weight of the charge.

The analyses of a number of specimens worked in the furnace are given in the two letters which I subjoin herewith :—

Consett Iron Company, Limited,

Consett, November 4th, 1871.

LABORATORY REPORT.

MR. W. JENKINS,

DEAR SIR,—Below I beg to hand you analyses of the samples of crude metal, refined iron, and puddled bar, used in and made by Spencer's mechanical puddling furnace.

With the exception of the phosphorus, of which it contains a rather large quantity, the pig is a good one for puddling purposes, with a fair amount of carbon, little silicon, and sulphur not too high.

In the refined metal (which, as it was taken before the breakdown, is not from the same heat, I presume, as the puddled bar) the silicon seems to be almost completely oxidised, and we lose a little of the phosphorus.

The puddled bars, like the other samples, contain rather more phosphorus then is advisable, but not more than I should expect from the quantity in the pig. In other respects they are of very fair quality. The excess of silicon in No. 2 over No. 1 would most probably be present as interposed slag.

As far as the chemical part of the process is concerned, the machine appears to answer its purpose very well.

You will observe I have not estimated the carbon remaining in the puddled bars. This is rather an important element, but I have not at present the necessary conveniences for doing so.

I am, dear sir,

Yours truly,

GEO. AINSWORTH.

	Pig Metal. Run from Cupola.	Iron. Refined in Furnace for 10 minutes, but not boiled.
Graphitic carbon	1·35	·30
Combined „	1·43	2·51
Silicon	·61	·14
Sulphur	·17	·18
Phosphorus	2·19	1·69
Manganese	·27	·14
Iron	94·26	95·08
	100·28	100·04

	Puddled Bar. From bloom once heated.	Puddled Bar. From bloom twice heated.
Iron	99·55	99·62
Silicon	·07	·34
Sulphur	·04	·05
Phosphorus	·10	·17
Manganese	·03	·02
	99·79	100·20

CINDER FROM METAL DURING THE BOIL.

Sesquioxide of iron	6·10
Protoxide	68·99
Alumina	4·72
Protoxide of manganese	·61
Lime	1·35
Magnesia	·18
Silica	12·90
Sulphur	·36
Phosphoric acid	6·46
	101·67

Metallic iron 57·82 per cent.

LABORATORY AND ASSAY OFFICE,
75, The Side,
Newcastle-on-Tyne, 19th October, 1871.

MR. EDWARD WILLIAMS,

DEAR SIR,—I have now completed the analysis of the samples of pig iron, &c., received from you, obtained during your inspection of the Patent Revolving Puddling Machine at West Hartlepool. The samples received were marked as follows:—

"No. 1.—Metal run from cupola."

"No. 2.—Metal refined in revolving vessel from 7 to 10 minutes, but not boiled (immediately before breakdown)."

"No. 3.—Cinder from metal during the boil."

"No. 4.—(Stamped '1') puddled bar from bloom once heated."

"No. 5.—(Stamped '2') puddled bar from bloom twice heated."

	"No. 1."	"No. 2."	"No. 4."	"No. 5."
Iron	92·983 %	94·395 %	99·555 %	99·399 %
Combined carbon ...	1·750 ,,	3·010 ,,	0·050 ,,	0·100 ,,
Uncombined ,, ...	2·020 ,,	0·310 ,,	0·010 ,,	0·030 ,,
Manganese... ...	0·302 ,,	0·220 ,,	0·129 ,,	0·057 ,,
Silicon	0·658 ,,	0·114 ,,	0·096 ,,	0·245 ,,
Sulphur	0·114 ,,	0·131 ,,	0·004 ,,	0·005 ,,
Phosphorus ...	2·173 ,,	1·820 ,,	0·156 ,,	0·164 ,,
	100·000	100·000	100·000	100·000

The cinder marked "No. 3" contained as follows:—(There was not sufficient of the sample to make a more minute analysis)—

Protoxide of iron	65·89	per cent.
Peroxide of iron	10·36	,,
Alumina of lime, &c.	4·84	,,
Phosphoric acid	6·81	,,
Silica	12·10	,,
	100·00	,,

The above analyses show that the pig iron operated upon was Cleveland pig, or worse, in regard to the amount of phosphorus it contains, and that the puddled bar made is equal, in chemical composition, to good puddled bar made by the usual process in ordinary puddling furnaces. The slightly inferior character of "No. 5" sample is probably due to the accidental presence of a portion of a cinder in the particular piece taken for analysis. The cinder "No. 3" is also similar to that produced in ordinary puddling furnaces.—I am, dear sir, yours truly,

JOHN PATTINSON.

Having read the paper, Mr. Spencer said he should like to make a few observations on balling up, and at the same time to express his thanks to Mr. Menelaus, for his encouraging and complimentary remarks, and to the other gentlemen who had spoken upon the subject of the furnace. He considered that the dividing of the mass into balls was an advantage, because they could use them for any purpose they required. If they had a ton ball to deal with, they must work in finished iron to large weights, but if they could bring it out divided into one or two cwt. balls, they could use these for forge, or for merchant, or for any other kind of iron ; but if from the machine, one ball only was required,—there was nothing simpler. He had found that the dividing of the mass depended upon the heat and the speed. If he did not want the division, he simply decreased the speed and raised the temperature, then he had the whole mass in one ball. The only advantage in getting one mass was that it could be hammered or squeezed at one operation, but it should not be forgotton that it had to be cut up and reheated before being rolled into bars. Some of the members of the Committee who had seen the heats from his furnace, would, no doubt, express themselves satisfied with the way in which the iron was divided and balled.

Mr. Menelaus said that Mr. Spencer had exercised a great amount of ingenuity and skill in the modifications which he had introduced into the rotary puddling machine, and he would state—and state it with great pleasure—that in his opinion Mr. Spencer had introduced a perfectly practical system of rotary puddling; that was, that he had produced a machine, which, on the rotary system, puddled most effectually and efficiently. He did not wish to draw any comparison between Mr. Spencer's machine and that of Mr. Danks, but he would say that in his machine Mr. Spencer had puddled, and puddled well, the ordinary irons with which the trade had to deal. With respect to the merit of dividing the heat into several balls, he knew that beyond all question it was very convenient to do so, because they could then use the ordinary machinery—the ordinary squeezers and hammers—for operating upon the iron so divided; but in giving his advice to Mr. Spencer, which he ventured to do because he was an old friend of his, he had said that in trying to divide the heat, which was, he thought, an exceedingly difficult thing to do, as it required a complicated form of vessel, and

also one of great size, he was trying to get over a greater difficulty than he would have to surmount in dealing with 10 cwt. or even 20 cwt. of iron. For himself, he would rather undertake to solve the difficulty of dealing with 10 cwt. or 20 cwt. of iron, in a mass, than to go in for designing a puddling vessel, which would bring out the heat in several balls; and he (Mr. M.) thought he sacrificed economy in yield—more particularly of coal—in working a large vessel, and a large vessel was necessary if the heat was to be divided into several balls. As he had before said, he considered that Mr. Spencer had exercised a great deal of ingenuity upon that most difficult problem, and the members of the trade ought to be very thankful to him for what he had done. He had certainly produced a very efficient puddling machine.

Mr. Edward Williams stated that he had had the advantage of seeing Mr. Spencer's machine at work, and he very gladly corroborated the opinion of Mr. Menelaus as to the good working and practicability of the machine for puddling iron. He had examined the fluid iron run into the machine and the puddled iron brought out, two good balls of very nearly equal size, in the first heat in a most efficient manner, and in a very short time. The quality of the iron produced was such as he had never seen before turned out by a single process of puddling from Cleveland pig iron. The machine was an old machine, and was in a very ricketty condition before he was able to go and see it, and it did not last very long after the experiments which he had witnessed; but he had noticed sufficient to convince him that, with Mr. Spencer's machine, puddling could be done very well. He agreed altogether with what Mr. Menelaus had said as to the undesirability of complicating the machine by making it produce more than one ball. He saw many more disadvantages about dividing the heat than in bringing out one lump altogether, although that lump might be heavy. He thought it was impossible to expect that they could ever divide the heat into balls of anything like uniform weight, and they would have the disadvantage of never knowing what weight of ball they were going to have; whereas, by bringing out a single ball, there would be a great saving—he had meant to say of waste—but it turned out now that there was no waste, but rather the reverse. In bringing out a single ball they would know how much they were going to produce, and they might be able to

estimate exactly what weight of ball they were to look for; and the cutting of it up into smaller pieces for other work would not be a very serious matter. He considered, therefore, that it would be better for Mr. Spencer to make a machine of such a size as to fit it for a single ball, and trust to cutting up the ball afterwards for such light purposes as might be necessary to his trade.

Mr. Snelus then made a few remarks relative to the analysis of the material produced by aid of Mr. Spencer's furnace. He said that, inasmuch as he had seen the analyses of Mr. Pattinson and of Mr. Ainsworth, and naturally had compared them with his own analyses of the material made in Mr. Danks's furnace, he would say that he was not only surprised, but highly pleased to see the remarkable manner in which the phosphorus had been eliminated according to these analyses. Of course, the chemical action was the same in Mr. Danks's as in Mr. Spencer's furnace. Therefore, he thought that whatever could be done in the one case could be done in the other. He would have been very pleased to show that it had been done in the experiments at Cincinnati, but there was one point of difference between the mode in which the Commissioners' experiments were made and the mode in which Mr. Spencer's were made, which was, that in Mr. Spencer's case the iron was run in melted, and in the American experiments, as they were all well aware, the iron was put in cold, and had to be melted in the furnace. The consequence was, that in Mr. Spencer's case the iron had a much greater chance of being purified. The point was, that in this analysis the phosphorus was reduced very low, but still it was a little too high; but this rather indicated that they might probably succeed in coming down to the right limit by-and-by.

A Member enquired the difference between the two machines.

Mr. Whitwell also asked whether the metal used by Mr. Spencer was the same as that used in America, or at Middlesbrough; because the iron made at Consett was half hematite, and half Cleveland pig. Therefore, there was much less phosphorus in it than in pure Cleveland.

Mr. Jenkins said it was not iron made at Consett that was alluded to in the analyses.

Mr. Snelus thought the analyses showed that the pig iron used by Mr. Spencer, contained a little over two per cent. of phosphorus. It was Middlesbrough pig, and happened on that occasion to have

more phosphorus than usual in it; but the pig iron used in America was also Middlesbrough pig, for one experiment, and that contained only one-and-a-half per cent. of phosphorus; still, with the two per cent. in the pig, Mr. Spencer's process reduced it in the puddled bar, or in the nearly finished ball, to a far lower point than he had found to be reached in the products from Mr. Danks's furnace. But, as he had mentioned before, there was a very great difference in the way the operation was performed; in the one case, the pig was put in melted, while in the other it was put in cold, and the melted pig gave a much greater facility for the elimination of the phosphorus than the cold pig.

Mr. Riley thought it would have been as well if Mr. Snelus had carried his results a little further with reference to the phosphorus. Mr. Snelus had pointed out in his paper the great difficulty in getting the slag out of puddled bar, and in ascertaining the amount of phosphorus which was due to the iron and not to the interposed slag. He had been working in that direction himself, and had found that the bulk of the phosphorus was in the interposed slag, and he was inclined to think that if this puddled bar had been melted in a clay crucible, and not in a black lead one, the result would have been even lower. This was an important point to ascertain, because from it they could learn whether it would do for making steel. He would like to ask Mr. Snelus to describe the crucible that he had used when he melted his puddled bar in the experiments to which he had referred, because if he had used a black lead pot, it appeared that some of the phosphorus in the slag would come into the iron; whereas, if it were melted in a clay crucible, he did not think it would.

Mr. Whitwell said that before Mr. Snelus replied to that question, he would like to ask another, so that he might combine the answers. He did not think that they had yet had very clearly explained the advantages or otherwise of putting pig iron or molten metal into the furnaces of Mr. Danks and Mr. Spencer—which did Mr. Snelus consider to be the most advantageous method? He had casually remarked that there was a much better chance of purifying the iron from phosphorus by putting it in molten; but on the other hand, he thought he had heard an allusion made by one or two gentlemen present, relative to the advantages of pig iron being melted in the machine, and although there might be

many disadvantages in doing it in that way, there was, as he had understood, a greater probability of the iron being purified.

Mr. Snelus, in reply to Mr. Riley, said that the crucible used had once been a plumbago one, but, as it had been in the furnace several times, the face of the plumbago had been burnt away, so that virtually it was only a clay crucible. It was white inside, and even if it had not been, he was certain that the black lead crucible, under the circumstances under which he had then used it (in a Seimens furnace, with a slightly oxidizing atmosphere), would not have had the power of reducing the phosphorus in the interposed slag. Another point bearing upon the question was, that when he melted the same puddled bar with pig iron, there was still, roughly, the same amount of phosphorus due to the interposed slag, as when he melted the puddled bar by itself; thirdly, there was the further result bearing upon the subject, that, in the attempt he had made to separate the slag, by crushing the borings of the metal, and then sifting them through a sieve, he had found that, practically, he could separate all the silica, and therefore, he might assume, the greater part of the slag also; but he had not removed the phosphorus, as could be seen in his report where he made the following observations:—"Some little of the phosphorus was removed with the slag, but the greater portion remained with the metal," and therefore, although he was at first inclined to hope with Mr. Riley, that the greater part of the phosphorus was in the slag,—he believed there was still a considerable portion in the iron. In reply to Mr. Whitwell, he would say that his opinion was that the reason why the puddling of melted pig iron gave a much better chance of purifying that iron from phosphorus and other elements that were to be removed, was that the temperature of the furnace was thereby kept up to a much higher point, and as he had noticed on one or two occasions, the temperature is a very essential element in the question,—the higher the temperature at which they could do the work, under the conditions existing in Mr. Danks's furnace, the better would be the purification obtained. The small advantage they would gain by melting down the pig iron in the furnace was much more than counterbalanced by the advantage obtained by putting the hot pig into the furnace, and thereby keeping up the temperature, by which means, he believed

they would have a product which would be purified to a greater extent than is possible under the present system.

Mr. J. A. Jones did not agree with the remarks that Mr. Snelus had made. If he referred to his own supplementary report he would find that during the melting of the pig iron a considerable portion of the phosphorus had gone out of it; fully one half. He believed, from a commercial point of view, there was a great advantage gained by putting molten metal into the furnace, but so far as the removal of phosphorus was concerned there was no advantage in the charging of molten iron. The reason why more phosphorus had been taken out by Mr. Spencer's process, as compared with that of Mr. Danks, was simply because he had used a better kind of fettling. The fettling he employed was mill tap cinder off a cinder bottom, which was wrought iron in combination with oxygen, and no natural product so pure as that could be obtained. The Iron Mountain ore of Missouri was the only one that could be compared with melted wrought iron in combination with oxygen. That was the way in which Mr. Spencer got a better result, as far as the removal of phosphorus was concerned; he had a better fettling to deal with. With regard to the division of the balls in the rotary furnace, he thought this was a step in the wrong direction. The time alone which was involved in dividing a mass of iron weighing from 10 cwt. to a ton into five or six balls, and in taking those balls out would cause an enormous loss, not only in keeping the machine going on puddling, but by reason of the waste in the furnace.

Mr. Snelus said that as Mr. Jones had spoken about his analysis, he might be allowed to point out simply that the "melted pig" referred to could not of course be taken at the moment when the first portions of it were fluid. He had had to wait until all the pig was melted down, and as the pig did not all do that at once, but only gradually, some part of the refining action would go on while it was melting, but this refining action was so rapid at this point, that he believed they would get phosphorus oxidized much more perfectly if they could put the pig in melted. By the time he had taken his sample, a good deal of the phosphorus had been removed in the crystalline pig, but at the same time more than half the carbon had been oxidized, and so it was quite certain that the refining action had gone on during the melting, and before he could get a sample, because it was no use

taking the sample when it was only half melted, nor indeed, until it was fully melted and had been mixed. The iron which was put in cold and melted down in the furnace, therefore, was partly refined. With respect to the purity of the mill tap cinder for a lining, and that the fact of that cinder being so free from phosphorus was the reason why the phosphorus was more perfectly removed by Mr. Spencer's process, he was afraid he could not quite corroborate Mr. Jones. He knew that even cinder from the oxidation of Bessemer steel—which certainly did not contain as much phosphorus as ordinary wrought iron—had more phosphorus than the Iron Mountain ore of Missouri, or than most of the ores which were used for the process, and from that fact he thought they could put in a much purer material, as far as the phosphorus went, than mill tap cinder, certainly as pure a material could be employed, and, therefore, he did not think that that was the reason why phosphorus was removed more completely in Mr. Spencer's process than in Mr. Danks's. He thought some other reason than that should be looked for.

Mr. Spencer, in reply to Mr. Whitwell, relative to the quality of the iron, said it was not Consett iron, and he was not in a position to say what brand of iron it was, but it was Cleveland iron, manufactured at a considerable distance from the works which he managed His analyses showed that the pig iron operated upon was Cleveland pig—or worse than that—in regard to the amount of phosphorus that it contained. But this was what he wanted to explain; it was not Consett iron, but the worst class of Cleveland iron, and it was so bad that they could not puddle it in the ordinary furnace at all, unless they mixed it with a much purer iron. It had been lying about the yard for a long time, and was next to worthless, but when they found out the plan which he had described, that had led them to employ it. The analysis was taken from a small puddling machine of about the same capacity as an ordinary puddling furnace, and with a surface of course much smaller than in the existing furnace. His present machine had about 100 square feet of surface in a single revolution, and he found the phosphorus eliminated very rapidly. In the first machine it took 50 minutes to puddle the iron—now but 15, or even 13 minutes.

Mr. Crampton enquired the largest diameter of the furnace.

Mr. Spencer said, in reply, it was a square furnace.

Mr. Crampton then asked the diameter across the corners.

Mr. Spencer said it was 4 feet 6 inches square, and 6 feet long. In respect of the dividing of the heat, he would follow out Mr. Menelaus's suggestion, to do away with the complication, as it was called. He gave a diagonal throw to the furnace—not to enable the heat to be divided, but simply to distribute the iron from end to end, and all over. The idea was not a new one, but still that was the object of it. The first heat that was produced from it came out in two balls, and in making the next he thought he would follow up that diagonal throw, which was done, and the division was still maintained. They were now erecting a furnace to puddle a ton of iron, but without the diagonal throw, and if it came out in one ball, it would not come out as he expected; but whether it was necessary or advisable to have a diagonal throw or not remained to be seen.

The President remarked that the paper of Mr. Spencer afforded another illustration of that singular fact that, while one man was perfecting a singular process in one part of the world, the advance of knowledge at the present day seemed so equally spread and distributed, that they found other men who were in no way connected with each other pursuing by a different path the same object, and often arriving at a successful issue at the same period. The consequence was that the remark was not unfrequently heard amongst patentees and inventors:—"Oh! somebody has stolen my invention." Now, he had never believed in the stealing of inventions. He knew that the progress of events and of scientific knowledge was such now, that there was a tendency in the human mind to combine facts that were common to all, and to so arrange these facts, that they necessarily arrived at similar conclusions at very nearly equal times. He thought it was perhaps fortunate that it was so, because a friendly rivalry and the little competition that was necessarily set up by people under these conditions, gave a stimulus to others to exert themselves more than they otherwise would do. They might hope that this sort of stimulus would exert such an influence, that the members of the Institute would soon have before them an excellent practical mode of working iron by mechanical means. He begged to convey the thanks of the Institute to Mr. Spencer for his paper.

ON THE ROTATORY PUDDLING FURNACE OF MESSRS. HOWSON AND THOMAS.

By Mr. R. HOWSON, Middlesbrough.

When we attempt to determine the direction in which improvement may be effected in the malleable iron manufacture, two starting points present themselves. The first commences with the assumption that the present system is altogether wrong—that the puddling furnace and all its adjuncts must be thrown aside, in order to make way for an entirely new mode of treatment. The other is the more cautious and tentative course, which seeks for gradual improvement rather than for sweeping innovations. It is no small merit of Mr. Danks's plan that it boldly attacks a system, and attempts to supersede it. Whether his furnace effects an immediate revolution in the trade or not, at all events it inaugurates a new method which will lead to a change sooner or later. It not only demolishes the old mode of puddling, but it demands new machinery and new processes of manipulation, and asks for a complete modernisation of all that is rude and old-fashioned. A consummation of this sort may, no doubt, be very desirable; but in the meantime, what is to be done with existing machinery and working plant? As far as this is concerned the transition must be gradual, and it is worthy of effort to endeavour to make it effectual; to cheapen the process; to improve the quality of the product; to diminish the labour of the workman, while avoiding at the same time the ruinous expense of having to begin entirely *de novo*.

It is with the latter view that the furnace about to be described was designed by Mr. Thomas and myself, so that it is not so much competitive with the Danks furnace, as subsidiary to it. It is proposed to retain many of the details of the ordinary puddling furnace, converting it into a mechanical puddler capable of turning out balls of such a weight as can readily be manipulated; to adapt the furnace, in fact, to existing working plant.

In making the attempt to puddle by mechanical means, the revolving principle is undoubtedly the most eligible, and I will

endeavour to show how it may be applied to an ordinary puddling furnace at no very great cost, and with successful results.

The diagram No. 1 shows a longitudinal section of the furnace, omitting unnecessary details. The fire-grate A is retained (although it may be advisable to modify it slightly) as far as the bridge. The hearth itself and the plates containing it are entirely removed, and the revolving chamber B is mounted in its place. The flue C and uptake D remain much the same as before, except that provision is made to adapt such parts as require it to their new conditions. The mode of causing the chamber to revolve it is unnecessary to describe, beyond stating that it is done by an ordinary engine, and that a 7″ cylinder with a 7″ stroke is amply sufficient to do all the work required, the gearing being arranged to give the machine from three to eight revolutions per minute. The chamber itself is of wrought iron, with cast iron trunnions, and it is constructed by preference of two cones fixed base to base. This is for convenience of lining, as will afterwards be described. The trunnions are mounted on rollers, and the rollers again on a carriage which runs on wheels in a direction across the axis of the furnace, as is seen dotted on diagram No. 2. The chamber can thus be moved laterally out of the axis of the furnace, opposite two screens F, which protect the chamber from loss of heat by radiation, but have holes in them through which the contents can be scrutinized and manipulated at any time.

When the ball is ready for removal, the chamber is traversed beyond the screens, and there slightly tilted, thus enabling the ball to be easily pushed out through the open trunnions. The lining is composed of bricks made of ground oxide of iron, and hard burnt previously to their being used. The oxide may consist of mill cinder, or natural ores, such as hematite or ilmenite, the precaution of course being taken that they are sufficiently refractory, and that they contain nothing injurious to the iron. The shape of the casing, as before observed, is favourable to this mode of lining, inasmuch as there are no corners requiring patching or stopping, and a lining thus formed may be worn down to the thickness of a $\frac{1}{4}$ of an inch before any part of it will give way. In order to supply and make up for the wear and tear which necessarily takes place, the ordinary scrap ball, or melted oxide, must occasionally be resorted to, and the inside can be glazed to any thickness, and at any part, by simply

turning the casing slowly round either in its normal or in its tilted position.

We now come to a feature in the arrangement which is of vital importance to the successful working of the machine. In consequence of the expansion of the casing by heat, it is necessary that the trunnions should not fit too tightly between their opposing faces, but that there should be a certain amount of play. The gap thus formed at the joint which is nearest to the fire-grate, would cause serious detriment by allowing an influx of air, which would, and does practically, cool the furnace, and waste the iron to a damaging extent. In order to prevent this, the contrivance is resorted to which is shown in front elevation in diagram No. 2 and in section in No. 1. It will be seen that the opening against which the trunnion works consists of two cast iron rings containing an annular space G between them. This annular space is either put in communication with the chimney by means of a separate flue, or by means of a pipe or passage E with the part immediately above the fire-grate. The latter is the arrangement here shown. The draught thus formed in the annular space causes the air which leaks in at the joint to pass away by the most direct route. In other words, the tension in the furnace and in the annular space are rendered equal or nearly so, and there is little or no leakage into the working chamber. In the early trials of the furnace, the value of this method of stopping the influx of air became at once distinctly apparent. Without it, the waste of iron and the bad quality of the product was such as to condemn the entire scheme, but immediately on its application the result was satisfactory—the puddled bar produced was of superior quality, and the waste was on the negative side—that is to say, there was rather a gain than a loss over and above the charge of pig iron put in.

I have endeavoured so far to explain that the ordinary puddling furnace may be converted into a mechanically acting machine, and without great expense may be rendered successful. The experiments have been conducted, as is generally the case at an early stage, under imperfect conditions. A furnace is now being built with more complete details, and I only regret that time would not allow of the results being presented in a form beyond dispute to this meeting.

Mr. Howson, having read his paper, said he had only to add that he exhibited at the meeting specimens of the oxide bricks referred to. The best mode of making them was ascertained experimentally by Mr. Frederick Jones, of the Newport Works. They were extremely hard and tough, and not so brittle as when cast in a melted state from the furnace.

Mr. President asked whether they were mixed with lime.

Mr. Howson said that in Mr. Jones's experiments he had mixed the oxide with lime and other substances. He had stated that 1 per cent. of lime rather improved the material. The specimens shown did not contain any lime whatever. He also exhibited a specimen of puddled bar made from half white and half grey forge iron, and in addition he submitted for inspection a sample of wire made from the same. He said it did not seem to signify much what in the shape of pig iron was put in, the product was always much above average quality.

Mr. J. A. Jones said there was one thing which would be interesting to all ironmasters. If the old puddling furnace could be utilized by this scheme, it clearly followed that a great deal of money would be saved in plant; but he would ask whether Mr. Howson considered that the withdrawal of the central chamber each time the furnace was drawn and charged did not cause an enormous loss of heat—that was, by the total withdrawal of the chamber; and he would like to ask whether his system could compare with that of Mr. Danks.

Mr. Head said that since Mr. Howson's aim seemed to be to utilize the ordinary puddling furnace, it would often happen that the chimney stack would be replaced by a boiler, as ironmasters could not afford to do without utilizing the waste heat. He would ask, if any engineers of Boiler Insurance Companies were in the room, what they thought would be the effect upon such boilers if the damper was withdrawn, say, twice every hour, and a cold blast of air allowed to rush through each boiler. That was a question which had not yet been raised, and was, he believed, of some importance.

Mr. Howson, in reply, stated that with regard to Mr. Jones's question about the difficulty of moving the furnace out from its working position, the means they had employed in the course of their experiments had as yet been of a very rude character, but

there was no mechanical difficulty whatever in making the machine perform this duty itself. In fact, it was the intention to make the engine wind the casing out so far that the charge could be inspected through the hole marked F on the diagram, and then replace it, the whole operation occupying only a very few seconds. This arrangement also gave them the advantage of being able to manipulate the iron on both sides of the trunnion; so that, if, in balling up, there should be any loose pieces unattached to the general mass, they could be worked up by means of a rabble inserted into either trunnion, while the furnace was protected from cooling by radiation by two screens, one on each side. In reference to Mr. Head's question, he might first remark that the trials they had made had been with a small flue underground in connection with the chimney. This answered very well, but of course it would not do when there was a boiler, and they proposed to resort to the plan shown in the diagram. It was very true, as Mr. Head had stated, that when the furnace was brought out the cold air would pass up the chimney flue, and tend to damage it. To prevent this, they had only to put the damper down; and, if the ordinary damper would not do, it would not be difficult to exclude the air by having a sliding door at the entrance to the flue. He apprehended, however, that the ordinary damper would be found practically sufficient.

The President asked for a description of the mode in which Mr. Howson proposed to tip the furnace so as to get out the ball, or the time when he would glaze or fettle the inside so as to prevent the fluid metal from always seeking the lower depth of the chamber.

Mr. Howson said the idea expressed in the paper was to tilt the chamber, so that the ball might be easily pushed out, and to take advantage of the same tilting to fettle the furnace by glazing it at every part with liquid oxide. Independently, however, of this arrangement, the shape was such that not only might the ball be pushed out without tilting, but he believed it would enable the furnace to be fettled easily by simply dragging the melted oxide about with a rabble while the vessel was slowly revolving. This plan might perhaps be the better of the two, because in this manner it was possible to work the lining into ridges, which were more favourable to the process than a smooth and even surface.

Mr. Head thought that some means should be adopted more efficient than an ordinary damper for the purpose of keeping out

cold air, or the alternations of temperature in the flues would be found highly detrimental, both to the durability of the boiler, and to the maintenance of an equable steam pressure.

The President thought that the period for which it would be removed would have a great bearing upon the question, and perhaps Mr. Howson would say how long it would be necessary that the movable portion should be detached.

Mr. Howson said the experiments had been hitherto of so imperfect a character that he could not give a very safe answer to the question. The shape of the vessel was favourable to getting the ball out quickly, and the charge might be introduced in a very short time. The whole process of taking out and recharging, he thought, ought not to take more than a minute.

Mr. Cowper asked if Mr. Howson had found the inclined inside surface of the chamber, when at the top, cause the melted ore or cinder to run down towards the joint at all. He would imagine, from the position of the top, that as the surface took up a portion of the cinder, there would be a certain amount of dripping between the two joints, which would require to be kept true and air-tight. He would also ask how he could keep the joint in shape, so as to prevent a draught of air going into the chamber. He supposed, no blast being described, the chimney would produce a slight vacuum in the chamber; if so, something more would be necessary to keep the two rings true, and make them air-tight. He understood there was a narrow space or circular chamber round about the ring joint, and a pipe leading from that space to the fire chamber or furnace, the idea being that if there was any leakage of air through the orifice, it would be supplied by air from the furnace,—that was hot air, and not cold air,—but that would only tend to make that joint so much the hotter. If cold air got in, it would be very injurious; but if hot air went in, there would be a chance of keeping the rings tolerably cool and true. There should be considerable play for the rotating chamber, because it had to be run in and out frequently, so that it must be free at both ends, unless there was some means of bringing one end up in some way.

Mr. Howson, in answer to Mr. Cowper relative to the shape of the furnace, said he ought to state that the exact shape shown in the diagram had not yet been in actual use. The form of the experimental furnace was somewhat similar to that of Mr. Danks,

that was to say, square at the ends, and parallel around the periphery. They had found the shape inconvenient in working, while the lining at the sides constantly gave way, and the improved form shown in the diagram was consequently designed. It would be observed that there were no vertical sides or corners, and it was for this reason easy to line, good to repair, and in other respects convenient in working. He presumed that Mr. Cowper quite understood the mode in which the leakage of air in the left hand joint was carried away. It passed away direct either to the chimney or to the fire-grate, so that there was no leakage into the furnace itself, and practically, the joint might be open to the extent of half-an-inch, and still there was no leakage, at all events, none of any consequence. At the same time, the inrush of air into the annular space had the effect of keeping the joint cool.

The President remarked that the members had had an opportunity of hearing the paper of Messrs. Howson and Thomas, and by a view of the diagrams, he had no doubt they would have been able to form an opinion as to the various details of that invention, also from the observations which had fallen from Mr. Howson in the present state of his invention. Though he was desirous of bringing it before the Institute on that occasion, yet he hoped in a short period to have it in a still more satisfactory state. They, however, felt obliged to him for bringing it under their attention, and he therefore proposed a vote of thanks to him for the paper which he had read.

ON DORMOY'S PROCESS OF MECHANICAL PUDDLING.

By MR. F. A. PAGET.

THE plan about to be described has been applied to forty puddling furnaces in different parts of Austria and France. The nearest of these works are at Rimaucourt (M.M. Paris, Guyot, and Huin), near St. Dizier, in the department of the Haute-Marne, France. Three of M. Dormoy's apparatus are now there at work, and the plan is being adapted to all the remaining puddling furnaces.

Its leading feature consists in placing a rabble, rapidly rotated by steam power, in the hands of the puddler. The ordinary furnace itself is left unchanged, except that the sides of the bed are set at an angle, instead of being vertical. It is not absolutely necessary to alter in any way the bed.

To adapt the plan to any common existing puddling furnace, a shaft conveying power from any prime mover is carried about six feet above the furnace. A belt from a pulley transmits the rotation of the shaft to another pulley or sheave below, which rests on the belt a little in front of the furnace door.—*(See Illustration.)* One end of the boss of the pulley is so jointed to a handle held by the puddler that the pulley can rotate without carrying round the handle. The other end embraces the outer end of the rabble, to which it is held by a cross-pin. The belt is thus made to rotate the rabble in any required position, in a somewhat similar way to the well-known rotating hairbrush. The number of revolutions employed is from three to five hundred per minute for white pig iron, and from eight hundred to one thousand for grey pig iron. The belt, while carrying and rotating the rabble, endows it with mechanical energy, and allows the stirring and puddling action to be directed to any portion of the molten metal. The rapidity with which the tool can be worked round gives the metal such an impulse that it turns horizontally on the bed, continually renewing the surfaces in contact with the atmosphere. The point of the rotating rabble, instead of being hooked, carries a disc. When the iron has "come to nature" this is replaced by a rabble having a short twisted point.*

The following are figures giving the work done at Rimaucourt by one of these furnaces during the first two weeks of last December:—

Working days of 24 hours... ...	1	2	3	4	5	6	7	
Number of charges or heats ...	23	23	23	24	24	24	25	
Days of 24 hours	8	9	10	11	12	13	14	15
Number of charges or heats ...	28	26	25	26	26	25	24	23

Total:—369 charges, during which the furnace was fettled only nine times, or on an average of one fettling per forty charges.

The charges of pig and of hammer-slag for the furnace bed

* As the iron can be "drilled through by the revolving rabble when come to nature," only the balling has to be done by the common hand rabble.

amounted to 97,060 kilos.; the amount of iron produced, 81,921 kilos.; with an expenditure of coal of 45,240 kilos.; which gives 1,185 kilos. of pig iron per 1,000 kilos. of wrought iron, with an expenditure of only 552 kilos. of coal per metric ton.

Briefly, the result of different trials shows an increase of at least 30 per cent. in the yield, with a proportionate diminution in the consumption of fuel. In spite of the greater number of charges, the puddler is very little fatigued.

This process, both in Austria—where it has been three years at work—and in France, has been found to eliminate phosphorus and sulphur to such an extent that inferior brands of pig produce iron equal to good charcoal iron.

The President said that that paper was an addition to their stock of knowledge and information on puddling, and would be appreciated by those present. He had no doubt that practical men would know how to look at each of the papers in their commercial and scientific value. In all things of that kind, it was of immense importance to the members of the Institute that these subjects should be brought forward irrespective of their particular merits, so that the members might have novelty and practicability combined. He proposed a vote of thanks, which was unanimously accorded.

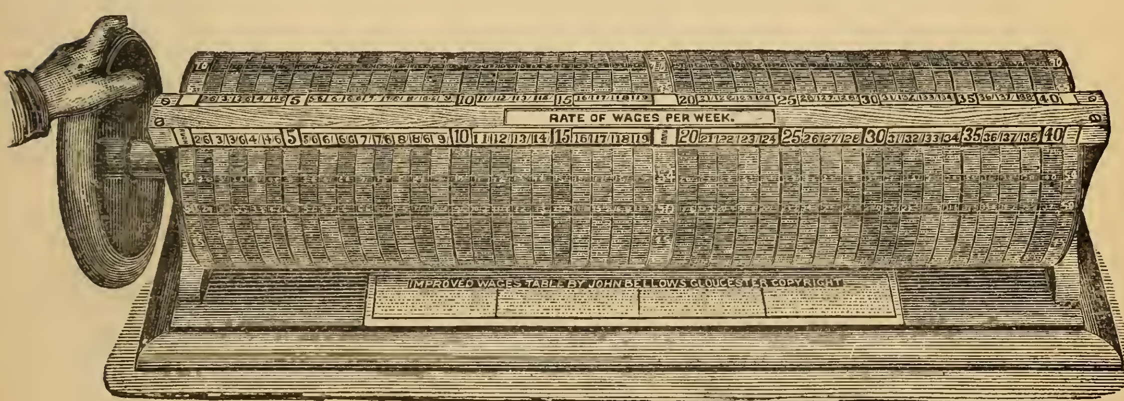
Mr. I. Lowthian Bell said that the numerous and very different character of the papers which had been brought up for consideration, and the interesting discussions which frequently had followed their being read, necessarily involved a great amount of labour and a great amount of responsibility on the chairman. That Mr. Bessemer had proved himself perfectly equal to that additional responsibility had been sufficiently apparent to the gentlemen who had attended the meeting. He, therefore, moved that the thanks of the members be given to the President.

The President briefly acknowledged the vote of thanks, and the proceedings terminated.

Mr. John Bellows, Gloucester, exhibited his Improved Rapid Wages Cylinder, for calculating the payment for day work on the new scale.

This instrument consists of a horizontal drum, carrying from 40 to 50 columns of figures representing the amounts at so many rates of wages per week, per day, or per hour, as the case may be. In front of it is a fixed bar or straight edge, on which are printed, in bold figures, the rates themselves, each rate standing opposite the column on the cylinder to which it refers. The whole series is divided into two principal groups, by the figures showing the hours, which occupy the centre; rates of wages under 20s. a week being on the left, and those from 20s. and upwards being on the right of this hour column.

The whole table is arranged vertically, in the reverse of the common method, so that the figures run *up* from 1 to 80, instead of running down. That is, a higher number is placed above a lower one, instead of below it. If the cylinder stands with the figure 1 of the hour circle next the bar, or straight edge, on moving it round towards the reader, which is done by touching the rim of a wheel at either end, one revolution shows him, every figure in turn, up to 80.



Suppose, for example, the time to be 31 hours, and the rate 21s. per week, a touch of the wheel throws the 31 of the central column round against the reading bar, and at the same time presents all along that bar the amount for 31 hours at every rate of wages, so that a single glance at the part marked 21/ on the scale shows the sum to be paid.

This will be best understood by the accompanying diagram, which shows a small part of the column for the hours, and those following it on the right. The large figures at foot represent them on the

reading bar, which must be supposed to stand about the 16th of an inch clean of the cylinder.

33	12/3.	12/10	13/5·
	11/11· 12/· 12/2.	12/6· 12/8. 12/9	13/2. 13/3 13/4
32	11/10	12/5·	13/·
	11/7 11/8 11/9	12/2 12/3 12/4	12/9 12/10 12/11
31	11/6	12/1.	12/8.
HOURS	20/	21/	22/

It will be seen that this process can be repeated through a long list of figures with much greater speed than is possible with a book, where leaves have to be turned over, and the page found, as well as the line, and part of the line, for each amount.

To further facilitate the rapid reading of the figures, the vertical columns are grouped in bands of different colours, such as yellow for the first three of the twenty series; blue for the three commencing the thirty series, and so on; while horizontally the figures are parted off in fives and tens by alternate lines of deep blue and red, respectively. An examination of the cylinder itself will show the practical use of this, for without any effort on the part of the user, to *learn* the several divisions and sub-divisions of the table which are thus secured, the eye accustoms itself, instinctively, to associate the several colours with these divisions, so that it becomes, with practice, but the work of a moment to hit upon any of the thousands of sums on the cylinder that may be required.

Thus far, the description of the cylinder shows how the amounts are read off for any number of entire hours. The fractions are provided for by the small horizontal lines of figures *over* each hour. [See diagram already given.] The figures above the hour, at the *left*, are the hour and a quarter; above, in the *centre*, the hour and a half; above at the *right*, the hour and three-quarters. This lateral arrangement of the quarters makes it almost impossible to read the wrong figure; a very common mistake in the ordinary wages tables, in which they are all printed in type of the same size, and in one perpendicular line.

It will be seen that all the clerk has to do, for such a figure, say, as $31\frac{3}{4}$ hours, at 21s., is to bring the 31, by the touch of the wheel, to the straight edge, or somewhere near it (for no very accurate

setting is needed,) and at the same time glance at the figure above and to the *right* of the 21s. for his answer, and so on.

The figures are always given to the nearest penny; but the nearest half-penny is shown at the same time by placing a dot up, and a dot down after such penny; when a half-penny more, or less, respectively, would be nearer the exact fraction due for the time indicated. The usual method of printing such figures, as $\frac{1}{4}$ and $\frac{3}{4}$ is objectionable for the simple reason that, as they are never actually paid, they only hinder the clerk's time. Thus, while $8\frac{1}{4}$ paid as 8d., and $8\frac{3}{4}$ as 9d., there can be no advantage in *not* printing the eight and the nine instead of the fractions shown.

Mr. G. W. Hick, Leeds, exhibited two working models of Hick's Patent Screen, with revolving bars, for screening and sorting coals, hematite ores, gravel, sand, &c. The Patent Screen is composed of a number of round or oval-shaped bars set in a frame, and *each bar* is made to revolve at a slow speed and in such a direction that any "choking" of the Screen or "grinding" of the material is rendered impossible. The bars are driven at the upper end by a cross shaft, on which are keyed strong cast iron worms, gearing into worm wheels attached to each bar end.

The spaces between the bars form the gauge of the coal. The process of screening and loading coals into waggons is carried on in a very expeditious manner (as much as 30 tons per hour by a single Screen), and as these Screens work with half the fall of ordinary Screens, the coals are not knocked to pieces, but are passed along the bars into the waggons with no more breakage than if dropped over the waggon side by hand. By the use of oval-shaped bars an easy undulating motion is imparted to the coals, which materially assists the screening by thoroughly feeding the spaces with small coal.

Whilst the coals travel over the screen continuously at a *slow speed*, the small coal is very thoroughly separated, and the dirt, shale, &c., removed easily by boys, without the labour of strong men with shovels and rakes, as hitherto employed for cleaning coals. The bars may be made of one uniform section throughout for screening into two wagons, or they may be made of a slightly decreased section for a certain part of their length, thus forming differential spaces for sorting into three wagons.

The coals, on being brought to bank, are shot out of the corve in the ordinary way into a slanting dead-plate, or into a hopper placed above the revolving bars, into which the coals are allowed to descend continuously. These advantages may be obtained without a great height of pit-bank.

The driving gear is noiseless, out of the way of injury and dust, and is easy of access.

A peculiar modification of screen is provided for thoroughly screening the slack, and separating therefrom the smudge, smithy coal, and nuts.

The screens are constructed throughout in the most substantial manner, and require but little power to drive them, which may be obtained by means of a leather belt from some existing machinery, or from a small engine driving a series of such screens.

They are applicable for screening hematite iron ores for blast and puddling purposes, and to almost every variety of solid substance on a large or small scale.

Mr. William Baker, Sheffield, exhibited samples of blistered steel from a converting furnace, showing the change from blister steel to grey iron, caused by the overheating of the furnace. The bars were laid in charcoal, and these specimens showed that in various places on the underside of the bars portions had melted out, and in some instances had dropped on the bars below. Whenever fusion had taken place, the blister steel (with its carbon wholly combined) had been converted into graphitic cast iron. An analysis made of contiguous portions gave the following percentages of carbon:—

Blistered steel	1·318 per cent.
Melted metal	2·263 „

The point of interest lay in the conditions of the change of white into grey iron being in this case one of heat alone. Thus, if the temperature of fusion be attained when iron is in contact with carbon, grey iron is formed.

The Machine Tunnelling Company exhibited cores of rock cut by the Diamond Drill. These had been brought up from holes of various depths, and showed the results obtained by the use of the Diamond Drill. By the use of this apparatus, great speed is obtained, as up to the depths yet reached (700 feet) scarcely any

difference in the working of the machine can be detected, at the same time complete cores or samples of the rock passed through are obtained. The cores are formed by the action of the annular crown or cutter set with diamonds, which cuts only a circular chase, isolating the core of rock which passes up the inside of the boring bars. The boring bars are not solid, as in the ordinary system, but hollow steel tubes in suitable lengths, down which water is passed, which runs to keep cool the diamonds, and at the same time to wash up the fine debris, which is the result of the cutting. The boring bars are as now used and arranged to receive a core 1 inch, which results from a hole 2 inches in diameter. They are revolved at speeds varying from 250 to 600 a minute, depending on the character of the rock to be cut. An ordinary portable engine is used to drive the machine. A hole was put down 690 feet deep for the Stanghow Ironstone Company, near Middlesbrough, in about two months time, and cores of the ironstone were brought up from that depth. The machine is also available for tunnel driving.

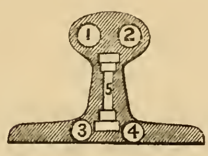
Mr. J. J. Bodmer exhibited specimens of bricks made by his process from blast furnace slag.

The annual dinner of the Institute was held at Willis's Rooms, on Wednesday evening, March 20th; Mr. Henry Bessemer in the chair. About two hundred members and visitors were present.

Results of Tensional Experiments on Specimens cut from "Iron Rail made from Puddled Ball," and from Sample of "No. 2 Iron," made in Danks's Machine.

The following results were obtained at the Royal Gun Factories, Woolwich, where, by permission of Colonel Campbell, specimens of Cleveland iron, brought back from America by the Commissioners, were tested. The terms "hard" and "soft," arise from one of the specimens being made red hot and cooled in water, to ascertain if it would harden, or rise in tensile resistance, either of which would indicate the existence of steely properties, or imperfectly converted iron.

IRON RAIL.

Reg. No. of Specimen.	Mark on Specimen.	Specimens cut from Sample, thus— (*See Diagram below.*)	Tons per Square Inch. Soft. Yielding.	Soft. Breaking.	Hard. Breaking.	Difference of Soft and Hard Specimens	Final Elongation. Soft.	Remarks.
9060	1		19·2	26·9			·085″	In the direction of the Fibre.
9061	2				26·8	0·1		
9062	3		20·8	33·7			·26″	
9063	4				29·6	4·1		
9064	5			13·64				Transverse to the Fibre.

No. 2 Iron.

Reg. No. of Specimen.	Mark on Specimen.	Specimens cut from Sample	Soft. Yielding.	Soft. Breaking.	Hard. Breaking.	Difference of Soft and Hard Specimens	Final Elongation. Soft.	Remarks.
9065	1		13·2	24·6			·453″	In the direction of the Fibre.
9066	2				28·2	4·8		
9067	3				30·7			

QUARTERLY REPORT

ON THE

PROGRESS OF THE IRON AND STEEL INDUSTRIES

IN FOREIGN COUNTRIES.

By DAVID FORBES, F.R.S., &c.,

Foreign Secretary to the Institute.

1872.—II.

A. METALLURGICAL TOPOGRAPHY.

Austria.—According to the most recent accounts, the manufacture of iron in this country continues progressing steadily, all the works being in full and active operation. The total production of iron ores and cast iron of all kinds, during the years 1869 and 1870, in the Austrian Empire, including Hungary, is reported to have been as follows:—

	1869.		1870.		Increase.
	Viennese centners.	English tons.	Viennese centners.	English tons.	English tons.
Iron ore extracted..	12,286,664 ...	680,606 ...	14,913,407 ...	821,901 ...	141,295
Cast iron produced.	4,965,544 ...	273,725 ...	5,024,827 ...	276,982 ...	3,257

A. Kerpely, the professor of iron metallurgy in the Royal Mining Academy of Schemnitz, in Hungary, whose excellent reports on the progress of iron smelting have been on several occasions referred to, has just published a work on the present condition and future prospects of the iron manufacture in Hungary. Das Eisenhuettenwesen in Ungarn sein Zustand und seine Zukunft, mit 2 Karten u. 1 Tafel, 1872, Schemnitz, Joerges. Wien, Faesy und Frick, a work which can be recommended as containing the most complete, as well as correct account of the Hungarian ironworks, which are severally described minutely, with criticisms and suggestions for their improvement. As there are more than one hundred and fifty ironworks so treated, some idea may be formed of the time and labour which the professor has devoted to this task.

Belgium.—Every branch of the iron trade of Belgium appears to be in a most prosperous condition, and since many years there has never been so much activity displayed, nor have quotations been so high as at present. It has been found impossible to keep pace with the orders which have flowed in from all sides, the entire produce of many of the ironworks being already engaged for a long time in advance, and contracts have been refused for delivery in the spring of 1873. Prices have advanced still more, owing to the difficulty of procuring a full supply of the raw materials, and many complaints are heard of the deficiency of coke which is now at from 18s. 9d. to 19s. per ton.

Many of the establishments are increasing the number of their blast furnaces; coke furnaces are being erected at the Providence Works, and also at Marcinelle and Châtelet in the central basin; it is reported that the furnaces of M. Dupont, at Chatelineau, are about to be blown in, and that M.M. D'Huart Frères, of Longwy, in the Moselle, are about to establish blast furnaces at Athus, for the reduction of the ores of that locality.

The total exportation of Belgian iron last year has increased, the figures being 259,000 tons in 1871, as compared with 250,000 tons in the preceding year. The exportation to Russia had, however, been very much less, and the quantity sent to France and the Netherlands also diminished, being respectively 4,000 and 7,000 tons less in 1871 than in 1870. The following figures show the more important items in the exportation of the last two years:—

	1870. Tons.	1871. Tons.	Increase. Tons.	Decrease. Tons.
Russia	64,000	22,500	——	41,500
Zollverein	58,000	96,000	38,000	——
United States	11,000	18,000	7,000	——
Austria	1,300	14,000	12,700	——

The importation of rough pig iron increased last year by about 5 per cent., having risen from 82,000 tons in 1870 to 86,000 tons in 1871, whilst the imports of iron generally, show an increase of about 4½ per cent., principally from England and Sweden, as those from France and the Netherlands had declined. According to the *Moniteur Belge* of the 6th April, the importation and exportation of iron ores and iron of all kinds, during the month of January this year was as follows:—

	Exported. Tons.	Imported. Tons.
Iron ores (and limailles) ...	13,006 ...	57,727
Pig and scrap iron	2,167 ...	7,520
Rails	3,936½ ...	54
Plates	1,482 ...	30
Other wrought iron	5,319½ ...	289
Wire	191 ...	117½
Nails	625 ...	19
Sundry articles	572 ...	205
Castings	190 ...	56

The total exportation of wrought and cast iron of all kinds, during the month of January, was 14,483 tons, which is an increase of 10,816 tons over January, 1871, but is still 3,162 tons less than in January, 1870, showing that the trade has not even yet attained the high point at which it stood before the war. In value, the exports of rails have increased 558,114 francs, and that of other rolled iron 608,160 francs, beyond that of the corresponding month last year. The importation of cast and wrought iron of all kinds amounted to 8,300½ tons, in the month of January, of which 6,431 tons of pig iron came from England. Of the iron ore imported, 44,796 tons came from the German Zollverein, and comparing this month, in 1872, with the corresponding one in 1871, it will be found that there is an increase in the value of iron minerals imported, of 786,682 francs, and of 418,840 francs in that of the pig and scrap iron. With respect to steel, Belgium imported in January, this year, 713 tons of cast, bar, sheet and wire steel, but only exported 16 tons in the same month. Preparations are, however, being made to increase this manufacture very largely, both as regards Bessemer, as well as other qualities of steel; the Martin-Siemens' process has recently been introduced at the Sclessin Establishment, where a furnace, constructed under the superintendence of M. Noblet, has just been put into work.

The exportation of steel in bars, which in 1870 only reached 320 tons, increased last year to 4,000 tons, of which 2,200 went to Turkey for railway purposes. To England, Belgium exported last year 653 tons steel, against only 3 tons in 1870, but to France the quantity was even less than before.

The number of workmen employed in some of the principal

ironworks of the province of Liége, at the commencement of this year, have been reported as follows:—

Couthuin Ironworks	62
Laminne, mines and works, Ampsin	600
Dumont frères works, at Schlaigneaux	175
L'Esperance mines and works, at Liége	1,890
Grivegnée do.	1,250
Jemeppe, rolling mills	100
John Cockerill, mines and works, Seraing ...	3,578
Jowa, Delheid & Co., ironworks, Liége	300
Jupille, rolling mills	150
Ougrée, blast furnaces and works	1,570
Sclessin, mines and works	2,653
Vesdre at Dobhain, blast furnaces	100

The report of M. Emile Laguesse, Ingénieur en chef Directeur des Mines, on the Industrie Minérale et Minéralurgique de la Province de Hainaut, has been forwarded us; it brings us down to the commencement of last year, and from it the following extracts are made:—In the year 1870, 94 iron mines, having a mean depth of only 69 feet from the surface, were in operation in this province, employing 318 workmen, and turning out 86,463 tons of raw ironstone, which, when washed, afforded 80,000 tons of clean ore, valued at 610,375 francs, or about £24,000.

Of the 46 blast furnaces existing, 18 remained idle and 28 were in blast, with a force of 2,648 workmen, and a production of 357,758 tons pig iron, valued at 25,996,316 francs, against 349,397 tons, worth 24,732,320 francs, made in 1869. In 1870, 8,105 workmen were occupied in the manufacture of wrought iron, with a consumption of 600,888 tons of coal and 420,668 tons pig iron, turning out a total of 305,969 tons, valued at 54,049,320 francs, against 293,309 tons, worth 49,356,525 francs in 1869. During these two years, the quantity of manufactured wrought iron turned out of the workshops was 5,727 tons, valued at 1,966,950 francs in 1870, against 4,605 tons, worth 1,676,200 francs in 1869; whilst the products of the foundries are returned at 33,086 tons, worth 5,932,059 francs in 1870, as compared with 29,780 tons, worth 5,302,750 francs in 1869.

The total value of the products of the iron industry of the

province of Hainaut for the five years, from 1866 to 1870, are given in francs as follows:—

	1866.	1867.	1868.	1869.	1870.
Iron ores	650,480 ...	434,320 ...	284,640 ...	533,960 ...	610,375
Cast and wrought iron	75,317,700 ...	65,084,592 ...	60,854,533 ...	81,067,795 ...	87,944,645

In Luxemburg, the extraction of ironstone from the mines in 1870 amounted to 1,010,000 metrical tons, of which 36·3 per cent. were smelted in the country, 38·4 per cent. sent to Belgium, and the remaining 25·3 per cent. exported to Prussia. With the exception of about from 5 to 6 per cent., the whole of this ironstone was of that kind of pisolitic ironstone called on the Continent minette; it is explored by open workings on the very regular and nearly horizontal beds of the calcareous marls in the oolitic formation. This ore costs about 1s. 8d. per ton to extract, and is sold at from 2s. 6d. to 3s. 4d. per ton, but as it contains a considerable amount of phosphorus, it does not produce a good pig iron, and is, in practice, generally used along with an admixture of iron of a better quality to improve it. The entire production of pig iron in Luxemburg in 1870 amounted to 158,000 metrical tons, but as mentioned in the last quarter's report, it is increasing so very rapidly, that it is estimated as likely even to exceed 300,000 tons in 1872.

Reports that immense discoveries of carbonate of iron have been made in Luxemburg and in the Grand Duchy, have very recently attracted much attention, but as yet no reliable information has been obtained concerning these deposits.

In addition to the list of works and periodicals directly or indirectly connected with the iron and steel industries in foreign countries, previously alluded to, may be mentioned the Bulletin de l'Union des Charbonages, Mines et Usines Métallurgiques de la Province de Liége, published monthly, and also a new fortnightly illustrated journal, the Chronique de l'Industrie, which has commenced its appearance in Brussels with the present year.

France.—The law just passed by the Assemblee Nationale regarding the merchant navy, will have considerable influence on the steel manufacture of France, since it imposes an additional duty on all goods, except the produce of French colonies, imported in foreign bottoms; from European countries, including, of course, the Mediterranean shores, this amounts to 0·75 francs (7½d.) per

100 kilogrammes (220 lbs.); so that the iron ores from Corsica, Elba, Africa, Spain, &c., which usually arrive in foreign ships, will be subjected to a tax of some six shillings per metrical ton (2,206½ lbs.), a duty which is out of all proportion, considering that such ores only cost from 6 to 8 shillings at the mine, and are annually imported into France at the rate of between 300,000 and 400,000 tons.

As regards the iron manufacture, things are looking very much better in all parts of France; the position of the ironworks in the Muerthe group is excellent, and their products deservedly in favour. All the establishments in the Muerthe Moselle have resumed work, and are in full operation. At Nancy, 18 blast furnaces, and at Longwy 9 are in work. Some new furnaces in the Haute Marne group have also been blown in, as well as some new coke furnaces pertaining to the Anzin Company. The works of the Marquis de Lambertye at Cons-la-grandville, in the Arrondissment de Briey, are again in operation, and the Orges and Châteauvillian furnaces are about to be put into blast. From St. Dizier the completion of two large furnaces, one at Brousseval, and the other at Marnaval, St. Dizier, are reported, and the journal "La Houille" announces the erection of six new blast furnaces in the Chavigny district.

The new rolling mills just erected by Messrs. Dumont & Sons, near Manbeuge, are now completed, and are calculated to turn out 1,500 tons per month.

Difficulties are still experienced from defective railway and river communication, many of the bridges broken down in the war not being as yet rebuilt, and the navigation of the Seine much interrupted by the works involved in their repair. Combinations have been formed to reduce as much as possible the inconvenience attendant on this state of things and the scanty means of transport: thus several masters in the Longwy district, M.M. Giraud, Labbé, Helson, and D'Huart have arranged for a daily train of 250 tons from the central basin, which is divided *pro rata* amongst the co-operating firms; at present, however, everything tends to maintain the high prices of coal and coke.

The productions of cast iron in France, during the second half of 1871, is returned at a total of 486,090 tons, of which, 87,334 tons are foundry, and 398,756 tons forge pig; this shows a diminution of 230,000 tons, or about 33 per cent. less, when compared with

the production of the second half of the year 1869, of which, one half is probably due to the loss of territory now annexed to Germany. During the second half of 1871, the make of wrought iron is reported at 69,491 tons of rails, 48,484 tons of plates, and 256,540 tons of other descriptions of wrought iron.

The importation of cast and wrought iron and iron ores into France, during the years 1870 and 1871, is returned as follows:—

Importations.	1870. Tons.	1871. Tons.	Decrease. Tons.
Pig iron and castings	139,113	91,107	48,006
Wrought iron	75,116	27,578	47,538
Iron ores	485,093	378,577	106,416

The falling off in the importation of iron ores is due principally to the smaller quantity of ore received from Germany. The details of the imported ores, show Algeria to have sent 155,608 tons; Belgium, 92,228 tons; Spain, 91,427 tons; Italy, 31,649 tons; Germany, 6,000 tons; Switzerland, 19 tons; and other countries, 1,646 tons.

In 1869, France produced 52,000 tons steel, or about twenty-nine times as much as in 1864, and in the first half of 1870 no less than 44,419 tons, so that it is estimated as soon as France recovers from the effects of the late war, that the country can turn out some 90,000 tons annually. In 1871, the Terre Noire Works sent steel rails to the United States for £30,000, which is the first occasion of any exportation of steel rails from France to that country; in the second half of last year 22,850 tons of steel rails were rolled in France, and 4,881 tons of steel in bars and other forms were also produced.

A paper by Lefaud, on "The Iron Ores of the Eastern Parts of France," with chemical analyses by Kirkhoff and Reuter, will be found in the "Revue Hebdom. de Chimie Scientifique et Industrielle" for January 18, 1872.

A new memoir by M. Gruner, professor of metallurgy at the School of Mines in Paris, has just appeared, and contains the results of his investigations on the action of carbonic oxide upon metallic iron and on the oxides of that metal, "Mémoire sur le dédoublement de l'oxyde de carbone sour l'action combinée du fer métallique et des oxydes de se métal par M. L. Gruner, 1872, 4to, pp. 66, Paris Imprimerie Nationale. A short notice of M. Gruner's results has

already been given in the last quarter's report for 1871, but the study of this memoir is recommended as throwing considerable light upon previously but little understood, although very important phenomena.

GERMANY.—About the middle of March, arrangements were completed for the amalgamation of three of the largest ironworks in Rhenish Prussia, viz., Heinrichshuette, New Schottland, and Dortsmundshuette, under the name of Union Company, the object of which is to carry on coal and iron mines along with iron and steel works, with a capital of £1,650,000 in ordinary, and £650,000 in preference shares. The principal people interested in this company are the banking firms of Rothschild of Frankfort, Oppenheim of Cologne, the Discount Company of Berlin, and the Provincial Discount Company of Hanover, in conjunction with several wealthy gentlemen of Rhenish Prussia. The works now belonging to the new company are well located. Heinrichshuette has four blast furnaces of large dimensions, a Bessemer Steel Works, fifty-six puddling furnaces, and a forge with rolling mill, besides the Karl Friedrich coal mine, and excellent iron mines of Spathic carbonate, brown and red hematites and black band ores, situated in Westphalia, Siegen, and Nassau. New Schottland also possesses four blast furnaces, two at Hasslinghausen, and two at Horst, at which place there are also Bessemer steel works, two large forges and rolling mills at Horst and Aplerbeck, and two mines of black band iron ore, situated respectively at Hiddinghausen and Neustueter. The Dortmundshuette comprises a large forge and rolling mills, with over 100 puddling furnaces, at Dortmund; two blast furnaces at Gothfresen, and the extensive Gluckauf coal mine, near Dortmund. These works, which are situated in the centre of the Ruhr coal basin, having ample railway facilities in all directions, are considered capable of producing annually from their own mines and works about 100,000 tons of pig iron, along with 150,000 tons of rails and other wrought iron, and 20,000 tons of steel.

In Western Germany, special attention is now being devoted to the production of Bessemer pig and to spiegeleisen, for exportation to Bessemer steel works in other countries; in consequence of the increased demand, the prices both of spiegeleisen, and of the manganiferous ores from which it is made, have advanced still more, and most of the ironworks are doing a splendid business.

The Bessemer pig from the Georg-Marienhuette, near Osnabrueck, is in great request for making steel rails and puddled steel, both in the vicinity, and as well as in Saxony in Austria. Even in 1870, during the war, this establishment paid a dividend of 8 per cent., and it is anticipated that for 1871 they will declare one of 15 per cent. With four blast furnaces in constant operation, the works turn out about 65,000 tons of Bessemer pig, using for this purpose about 160,000 tons of ore along with 150,000 tons of coal. The ores are somewhat calcareous, consisting of hard crystalline manganiferous carbonates of iron and soft brown hematites, derived from the Hueggel hills in the Teutoburger Wald, about seven miles south-west of Osnabrueck, where they occur in a deposit from 18 to 37 feet thick, dipping 26° to the north-east, which is known to extend some $2\frac{1}{2}$ miles, and is worked in open terraces at the mines of Hermine, Brockmann, and Bothenberg, but underground in the Hedwig mine; in 1870, these mines yielded 180,963 tons of iron ore.

The larger portion of the coal consumed in these works comes from Westphalia, but in 1870, 45,025 tons were obtained from the Oesede and Bargloh collieries, to the south-east, which are connected with the works by a railway. The works were commenced in 1858 with one blast furnace, but did not prove a success for the first few years; they now, however, have six blast furnaces, and employ 1,500 men. The blast furnaces are 58 feet high, with from 13 to 16 feet diameter, and a capacity of from 6,131 to 8,286 cubic feet, and are worked on Luhrmann's system of closed breasts, with constant efflux of slag through the slag openings. The blast is supplied by five blowing engines, with horizontal cylinders, the steam cylinders being 51 inches, and the blowing cylinders 108 inches in diameter, whilst the stroke is 7 feet in both. The piston rods are hollow, 14 inches diameter, and $1\frac{3}{4}$ inches thick. The pressure of the blast is from $4\frac{1}{2}$ to $4\frac{3}{4}$ lbs. on the square inch, and the engines work with from 45 to 46 lbs. steam pressure, $\frac{5}{8}$ expansion, and 21 strokes per minute. The hot air stoves are on the free suspended pipe system, each having 1,400 square feet of heating surface, and are capable of raising the blast to a temperature of 850° to 930° Fahrenheit. Three such stoves, heated by separate fires, are attached to each blast furnace. A detailed description, with plans of the Georg-

Marienhuette, by Funk, will be found in the Zeitschr. d. Hannover Archit. u. Ingen Vereins, 1871, Bd. 22.

The following list of prices is given as those ruling in February this year, and when compared with those stated in the last quarterly report, show a still further advance:—

Iron ores, spathic carbonate	£1	4	3	per ton.
„ „ calcined ...	1	9	4	„
„ specular	1	7	0	„
„ brown manganiferous hematite	0	19	8	„
„ Nassau red hematite (45 °/₀)...	0	15	0	„
Pig iron, grey, charcoal-made	6	18	0	„
„ do., coke-made	6	0	0	„
„ white & mottled, charcoal-made	6	12	0	„
„ do., coke-made...	5	14	0	„
„ Bessemer, coke-made	6	6	0	„
Spiegeleisen, charcoal-made	9	0	0	„
„ 1st quality, coke-made ...	8	2	0	„
„ 2nd do., „ ...	6	12	0	„
Wrought iron, puddled bars	8	14	0	„
„ hammered bar iron ...	12	0	0	„
„ rolled „ ...	11	14	0	„
„ flat „ ...	11	2	0	„
„ wire iron	11	8	0	„
„ slabs	12	4	0	„
„ sheets, 1st	16	16	0	„
Steel, puddled	12	12	0	„

The principal railways of the Rhenish provinces and their connections have concluded an agreement by which all raw materials, like coals, ore, limestone, &c., are to be carried at the rate of one pfenning per 100 kilogrammes per mile, or about five-eighths of a penny per ton per mile, an arrangement calculated to be of much importance to the iron trade of these districts. The general state of the iron trade on the Rhine has been exceedingly brisk, and has now quite recovered from the effects of the war. The dividends declared by the Aplerbeck Iron Company was at the rate of 8 per cent., Arenberg in Hoerde 6 per cent., and the Bochum Cast Steel Company 10 per cent. The tenders sent in for steel tyres for the East Prussian Railway were lowest from Rhinish Prussia, which were considerably below those received from England. Large orders

for Pomerania and Eastern Prussia have been secured by the firm of De Wendel of Hayange, in the annexed Alsatian provinces. A report on the condition of the iron blast furnace industry in 1871, in the Rhinish and Westphalian districts to the east of the river, has been published by W. Hupfeld in the Zeitschr. d. Berg u. Huettenms. Verein f. Kaernthen, 1872, No. 2.

In Silesia, a company bearing the name of the " Vereinigte Laura und Koenigshuette," with a capital of 6,000,000 Prussian dollars, was established in June last, for the purchase and working of the ironworks and collieries known under these names, both of which were the property of Count Henckel of Donnersmarck, who, however, had only purchased the Koenigshuette works from the Prussian Government the year before, when they were put up and knocked down to him by public auction.

During the first half-year of this new company's existence, which is just terminated, the production of pig iron from their blast furnaces amounted to 43,106 metrical tons, nearly the whole of which had been utilised by the puddling furnaces and rolling mills of the company, which, during the same period, turned out 31,987 tons of wrought iron, chiefly in the form of rails and plate.

The details of the iron and steel industries of Prussia, during the year 1870, were entered into in our last quarterly report, and in connection with this the following figures, obtained from another source, are given for comparison :—

Iron ore extracted in 1870	... ...	2,676,400	tons.
Pig iron made ,,	... ...	1,123,422	,,
Castings made ,,	... ...	236,856	,,
Wrought iron made ,,	... ...	627,900	,,
Plate and wire made ,,	... ...	128,193	,,
Steel of all kinds made ,,	... ...	157,901	,,

According to the mining and metallurgical statistics of the kingdom of Saxony, as given in the Jahrbuch fur den Berg und Huettenmann auf das Jahr, 1872, the total amount of iron ore raised to the surface during the year 1870, which is the last official return, did not amount to more than 16,061 metrical tons, valued at under £12,000, the details being as follows :—

		Centners.	Centners.	Value in Prussian dollars.
Freiberg district—				
	Freiberg proper ...	7,695		
	Altenberg...	22,995		
		——— ...	30,694 ...	28,722
Marienberg district			760 ...	63
Swarzenberg ,;			289,763 ...	49,775
Total			321,217 ...	78,557

The Saxon Steel Company, whose works are at Doehlen, near Dresden, have been extremely successful, and have paid a dividend of 22 per cent. on their last year's operations.

A detailed description, with chemical analyses of the clay iron-stones of Kressenberg, in Bavaria, by Dr. Schafhauetz, will be found in Sud Bayerns Laethœa geognostica.

Much attention has been given of late in Germany to the question of machine puddling, and the probable influence which its general introduction may have on the iron trade of the country. A long article on the subject, by M. Cappe, in the "Gluckauf" journal, concludes by stating, "Although the results already obtained do not appear so great as to lead to a complete revolution in the system of puddling, that, nevertheless, if, as appears probable, it does economise in reheating the balls, and reducing the consumption of coal and manual labour, the Danks furnace may have a great future wherever the ore is cheap, the pig iron and labour dear, or where good workmen are scarce.

The great cast steel works of Friedrich Krupp, at Essen, in Rhinish Prussia, employed during the year 1871, 8,810 workmen, and turned out 75,000 metrical tons of cast steel, in the form of axles, tyres, rails, shafts, rolls, boiler plates, springs, artillery, projectiles, &c. The plant consisted of 528 annealing and cementing furnaces; 260 heating, re-heating, and puddling furnaces; 245 coke furnaces; 130 miscellaneous furnaces; 169 forges; 174 steam boilers; 343 lathes; 73 shaping machines; 130 planing machines; 172 punching machines; 303 other machines, of all kinds; and 58 steam hammers, varying in weight from two hundredweight up to 30 tons, the three larger being of about ten, twenty, and thirty tons respectively. The steam engines on this establishment were 265 in number, varying in force from 2 up to 1,000 horse-power, and representing in the aggregate no less than 8,559 horse-power.

The recent German contributions to the literature of the iron industry include:—

Das Roheisen in Bezug auf seine Verwendung zur Eisengiesserei von A Ledebur. (Cast iron considered in its applications to founding). 2 lith. Tafeln. 1872. Leipzig. Arthur Felix. 1⅓ thlr.

Studien ueber die Waermeverhaeltnisse des Eisenhohofenprozesses von Richard Akerman. Uebersetz von P. Tunner. (A translation of Akermann's memoir on the conditions of heat in the blast furnace process). 2 lith. Tafeln. 1872. Leipzig. Arthur Felix. 1⅓ th.

Italy.—The mines of iron ore at San Leone, near Cagliari, in the Island of Sardinia, which are now being worked by the French Company M.M. Petin et Gaudet, are located in the Silurian Slates, and are lodes running nearly magnetic north and south, with an underlay to the west; they contain an abundance of garnets with a little quartz, and the ore, which is a native oxide of iron, has the following composition:—

Sesquioxide of iron	62·00
Protoxide of iron	24·00
Oxide of manganese	0·80
Sulphur	0·20
Loss on ignition	13·00
	100·00
Per centage of metallic iron ...	62·06

The exportation of iron ores from Italy to other countries, especially France, which last year imported 31,649 tons, is gradually increasing, the ores themselves being in general both rich and of extremely good quality.

Spain.—All the information received from this country since our last reports, relates exclusively to the activity which English enterprise and capital is now displaying in developing the extensive and valuable deposits of rich iron ores, known to exist in many parts of the Peninsula, in order to supply the British ironmaster with ores of high quality, suitable for the manufacture of Bessemer steel; amongst these we find a new company, entitled, "The Malaga Magnetic Iron Ore Company, Limited," which has been brought out recently, for the purpose of working and shipping to England the rich and extensive deposits of iron ore in the valley of La Palmitera, about 16 miles from the Coast of the Mediterranean. The two deposits called respectively "La Colosal" and "El

Auxiliar," appear to be but parts of one great lode of native magnetic oxide of iron, the quality of which may be judged from the following analysis, by Dr. Wallace, of Glasgow.

	La Colosal.		El Auxiliar.
Peroxide of iron	68·04	...	70·40
Protoxide of iron	21·37	...	21·96
Oxide of manganese	1·40	...	traces
Lime	·20	...	traces
Magnesia	1·18	...	3·36
Alumina	3·42	...	1·50
Silica	2·60	...	0·30
Sulphur...	0·04	...	0·04
Phosphorus	0·01	...	—
Water, with traces of carbonic acid	1·74	...	2·44
	100·00	...	100·00
Percentage of metallic iron ...	64·25	...	66·36

There is no doubt about ore of this character being well adapted for the production of pig iron, suitable for conversion into Bessemer steel, but it is a mistake to imagine, as stated in Dr. Wallace's report, that such ore will be more readily smelted than the Whitehaven hematite, as it is well known to all who have had practical experience in the working of such ores in blast furnaces, that the native sesquioxides of iron are much easier of reduction than the magnetic oxides which, unless submitted to a previous calcination, are as a rule very refractory. The importation of this ore into England would, no doubt, be welcomed by our ironmasters, yet it is to be feared that the freight from the Mediterranean to this country will, in practice, prove much higher than anticipated in the prospectus of the Company, if the exportation of this iron ore is to be conducted upon anything like a large scale.

Several other mines of magnetic oxide of iron in the South of Spain and in Portugal are understood to be in the market for purchase, but as yet have not been taken up.

The exportation of iron ore from the Bilbao district of England is now carried on as actively as the present extremely defective arrangement for transporting the ore to shipping places on the river and for loading it into the vessels will admit of. A considerable quantity of ore is sent down the river in barges, from the brown

hematite mines, located above the city of Bilbao, and loaded into vessels at Olaveaga, some four miles below the town, to which place ships drawing up to eighteen feet of water can ascend; the main supply, however, comes from the great mines of hydrous red hematite in the cretaceous formation at Somorostro, from which at present, there is only a single line of rails (another is, we understand, projected if not already commenced) to the shipping port of San Nicolas. This does not, owing to the defective means of loading from want of sufficient quay room, and the customs regulations which prohibit night work, admit of more than 1,300 tons per day being loaded, so that there are at present, no hopes of exporting more than between 400,000 and 500,000 tons per annum, yet it is notorious that about 600,000 tons are already contracted for for delivery this year, and the port is already crowded with vessels waiting their turn, and incurring enormous sums for demurrage, which in greater part will fall on the charterers in England, so that the cost of the Bilbao ore when delivered in Welsh or English ports is out of all proportion high, owing to these impediments in the way of getting the ore from the mines placed on board the ships. The inauguration of the mineral railway from the mines of the Bilbao Iron Ore Company, at Galdames, to the mouth of the river of Bilbao at Sestao, took place on the 30th January, and the works are being vigorously prosecuted.

Another English company, called the Spanish Hematite Company, limited, with a capital of £150,000, in £10 shares, has commenced working of the San Miguel Iron Mines, near Irun, in the province of Guipuscoa, with the object of exporting hydrous hematites and spathic carbonates of iron to England and France. The mines of this district, or of the Bidassoa, as they are usually termed in France, exported to that country, before the stagnation in the iron trade of France caused by the war with Germany, about 1,500 tons of iron ore per month, and are again attracting attention, as will be seen from a long article upon them in the Annales des Mines, Series VI., vol. XX., pp. 552-559. Their development hitherto has been retarded mainly from the want of railway communication from the mines to the shipping port.

The Santander Mining Company, with a capital of £80,000, in £10 shares, has also been brought out, with the object of acquiring and working certain iron and other mines in the north of Spain.

SWEDEN.—The present high prices for iron, and especially so for the higher qualities of charcoal iron, have, as might be expected, done good service to the Swedish ironmasters, who have made every effort to increase this production to its utmost, this being, however, limited by the annual supply of charcoal which can be procured from the forests, has not allowed of being much augmented either by any considerable extension of the present or by the erection of new works for the production of charcoal iron; attention has, therefore, been directed to the utilization of the superabundance of rich iron ores in the central iron district of Sweden by exporting them to England and Belgium, and also, on a smaller scale, by smelting the iron ores on the spot with coke from England, brought over as return freight by the ships which will carry iron ores to that country.

Arrangements are, it is understood, now being made, both on English and Swedish account, for working the iron mines located along the line of the new Swedish Central Railway, and for exporting the ores as soon as that railway is opened for traffic, which is expected to be some time this summer. The quality of these ores is unexceptionable, and in richness they vary from 50 to 60 per cent. metallic iron. Although less prices have been announced, it is not probable that these ores can be delivered on the east coast of England, owing to the long overland carriage, under, at the lowest, twenty-five shillings per ton.

An English company, entitled, "The Swedish Central Iron and Steel Company, Limited," with a capital of £325,000, divided into 6,500 shares of £50 each, has been established, and commenced operations with the twofold object of working both charcoal and coke furnaces in connection with Bessemer steel works and rolling mills. At Bjorneborg, in the western part of this district, their operations are confined to the manufacture of charcoal iron for the production of Bessemer steel plates and tyres of the finest quality; whilst at Frotuna, two large blast furnaces are in course of erection for smelting iron ores brought from the iron mines situated along the Swedish Central Railway, from which an ample supply can be had at extremely low prices. The fuel to be employed is coke from England, and the product, after conversion direct from the furnaces into Bessemer steel, is to be rolled into rails for consump-

tion in Sweden, and exportation to Russia and Germany. The richness, purity, and cheapness of the iron ores, the magnificent water power, and ample supply of cheap labour at command, and the proximity of the markets for the manufactured products, are advantages which are expected to more than counterbalance the extra expense of the combustible, and are considered to ensure the success of the undertaking.

An important paper on the development of heat in the Bessemer process, "Orn vaermealstringen under Bessemer processen," has recently been published by Herr Richard Akerman, of the Iron Office, and takes into detailed consideration the amount of heat generated by the combustion of the different elements presented in the converter, as also the effect of hot blast when applied to the Bessemer process.

UNITED STATES.—The annual meeting of the American Iron and Steel Association was held at New York, on the 11th January last, under the presidency of Mr. Samuel J. Reeves. The report of the Secretary, Mr. Henry McAllister, jun., was read, and discussions took place on subjects connected with the iron and steel trades, the entire tenor of which was to advocate and defend the protective duties, and to attempt to prove them as advantageous to the country in general as they are, no doubt, to the ironmasters of the United States in particular.

The National Association of Bar Iron Manufacturers assembled at the Continental Hotel, Philadelphia, on the 10th and 11th of January last, under the presidency of Mr. James J. Bennett. The objects of this Association are stated to be "for the purpose of obtaining full statistics of the iron trade throughout the world, and effecting frequent interchange of ideas, improving the manufacture of iron in the United States, and securing harmonious action in all matters pertaining to the iron interests." The report of the Secretary was a very lengthy document, and as it contains a retrospect of the state of the iron industry of the United States in 1871, probably more correct than any other data at our command at present, a rather full abstract of the portion relating to the production of iron in the States is here appended.

The estimated production of pig iron in 1871 is given as follows:—

	Tons.	Tons.
Anthracite pig—		
Lehigh region	275,000	
Schuykill	142,000	
Upper Susquehanna	118,000	
Lower do.	118,000	
East Group (E. and N. of Pa)	210,000	
	———	863,000
Raw coal and coke pig iron		600,000
Charcoal pig—		
New England	35,000	
New York, New Jersey, Pennsylvania, and Madison ...	137,000	
Western States	200,000	
Southern do.	15,000	
	———	387,000
Total in tons of 2,000 lbs. each ...		1,850,000

The details of the statistics are as follows:—

Pennsylvania, 38 blast furnaces produced 378,000; three others, each capable of turning out 9,000 tons, are in course of construction—of the ores employed, 70 per cent. was hematite from Lehigh, Berks, and Northampton counties, the remainder from the mines of New Jersey, South Mountain, Pennsylvania, and magnetic ores. The coal is from the Lehigh anthracite mines, and from the Wyoming and Schuykill district, whilst the limestone is from the immediate neighbourhood of the furnaces.

The Schuykill region is equal to a make of 160,300 tons, with all the furnaces in blast; the Leesport and the Hooven furnaces at Norristown, representing 21,000 tons, were, however, standing idle.

Of the regions of Pennsylvania, 7 furnaces, representing 70,000 tons, exist in Pittsburgh and immediate vicinity, whilst six more are in course of erection, four of them 75 feet high, two being 18, and two 20 feet diameter at the boshes, these are estimated to add, in 1872, 90,000 tons more, and thus make a total of 160,000 tons pig iron in Pittsburg in 1872.

In the Shenango valley, 23 furnaces produced 192,000 tons, and in the course of construction are 3 blast furnaces at Wampum, equal to an estimated annual make of 47,000 tons, 1 at Newcastle,

23,000 tons; 1 at Sharon, and 1 at Sharpsville, each equal to 12,000 tons. The remaining production comes from the districts of Harrisburg and Juniata, Lower Susquehanna, Danville, and Johnston.

The Mahoning Valley, with 21 blast furnaces, yielding 203,000 tons, is the prominent iron producing region of Ohio, using its own block coal along with ores from Lake Superior.

No statistics had been received from the blast furnaces at Ironton and its vicinity, but at Cleveland, two blast furnaces turned out 17,000 tons.

The Lake Superior region of Michigan produced 958,520 tons iron ores in 1870, and nearly 1,250,000 tons in 1871, which employed above 200 vessels in its transport. Within the district are fifteen furnaces, which yielded 50,000 tons pig iron, whilst outside it, in Michigan, are two furnaces at Wyandotte, of capacity of 8,000 tons, along with one or two others not noted.

The increasing iron production in the North West is remarkable, especially in Wisconsin, where there are now ten furnaces in blast, with a total product of 67,900 tons. Of these, two furnaces at Milwaukee make 30,000 tons, with bituminous and anthracite coal and coke, all the rest are charcoal furnaces, three of these using Wisconsin ore, turned out respectively 2,500, 2,700, and 3,300 tons, but of the five others, four made 6,000 tons each, and the remaining one, 5,400 tons, being much larger; the average consumption of charcoal in a 6,000 tons furnace being 700,000 bushels, equivalent to 21,000 cords of wood, which, on an average, is reckoned at thirty cords to the acre of land. The average price was eight cents. per bushel, and 100 bushels were required to the ton of pig iron.

Missouri has fifteen blast furnaces, and produced 129,500 tons, of which 44,500 was charcoal pig iron made in eight furnaces, three of which were driven by cold, and five by hot blast; the remaining 85,000 tons were made with coal in seven furnaces.

At Chicago, two furnaces, with a capacity of 35,000 tons, consume coal from Erie and Pittsburgh, in Pennsylvania; and at Joliet, two furnaces produce 25,000 tons.

Indiana has seven blast furnaces consuming the block coal of the locality, and smelting Lake Superior and Iron Mountain ores; the pig produced is now being extensively employed for conversion into Bessemer steel.

No complete report has been received from Georgia, Alabama,

Kentucky, Tennessee, Virginia, or from the Northern and Eastern furnaces.

The total consumption of iron in the United States, for 1870, is given at about 2,000,000 tons, of which one half went into railroads; this quantity is equivalent to 115 pounds per head in the population; in 1867, the consumption was, in England, 189, and in France, $69\frac{1}{2}$ pounds per head.

Before closing the proceedings, which adjourned to meet in Pittsburgh in May, the Association adopted the following resolutions, which afford the most convincing proofs of how much the iron trade of the United States is wedded to and dependent on the protective duties by which external competition is, to a great extent, annihilated.

"We, the bar iron manufacturers of the United States, in convention assembled at Philadelphia, representing the kindred interests over a million workmen, the value of whose products, in 1871, amounted to 900,000,000 dollars, do resolve:—

First.—That in the adjustment of the national revenue, the wages of labour and the interest of capital should be taken into account, and no changes made to their injury.

Second.—That the enormous increase of our iron manufactures within the last decade, and the collateral benefit to the industry of the whole country, can be traced to the protection given to the iron interests during that period.

Third.—That the present prosperity of labour in the United States, enabling the working man to occupy a higher position in social life, with privileges and comforts unknown to the workmen of any other country, is attributable to the liberal wages paid for labour under a protective policy.

Fourth.—That these wages are dependent upon the price of the manufactured article, and a reduction in the tariff means a reduction in the wages paid to American labour.

Fifth.—That the present duties upon iron are not giving to labour and capital more than a fair return for the work performed, and the risks involved, and that any reduction in the tariff would eventually close our mills and furnaces, leave without means of support our workmen, prove disastrous to the farmers and shopkeepers, and cripple all other industrial pursuits.

Sixth.—That further, as American citizens, we protest against

the adoption of any policy which shall retard the development of our country, and place us in a condition of dependence upon foreign nations for our manufactures."

Notwithstanding the detailed account of the production of pig iron in the United States, given in the report of the Secretary of the Bar Iron Manufacturers' Association, this body does not appear to have paid anything like the same attention to the statistics of their own particular branch, the wrought iron trade, so that we can only give a summary of its condition during the last eight years, in the following tabular statement, given on the authority of the Secretary of the American Iron and Steel Association:—

Year.	Rails.	Other than Rails.	Total annual make.
1864	335,369	536,958	872,327
1865	356,292	500,048	856,340
1866	430,778	595,311	1,026,089
1867	462,108	579,838	1,041,946
1868	506,714	598,286	1,105,000
1869	593,420	642,420	1,236,006
1870	620,000	710,000	1,330,000
1871	750,000	713,000	1,463,000

The last year's estimate is only an approximative one, as the returns are not yet made up. The number of rolling mills of different descriptions in the United States in 1871 is stated at nearly 300; and, as considerable extensions are being made in all directions, a larger increase in the make for this year is anticipated.

Mr. J. W. Forster, in comparing the iron ores of the Lake Superior district and of Missouri with those of Sweden, gives the former the preference, owing to their, according to him, containing less sulphur, and not requiring calcination before smelting in the blast furnace. He does not, however, seem to be aware that Swedish ores exported to and smelted in Belgium and England are not calcined, but charged into the furnace in the raw state, and that the reason why in Sweden these ores are invariably calcined is not on account of the sulphur they contain (a large number of them being practically free from sulphur, as well as phosphorus), or because a preliminary calcination is imperative, but because long experience has proved that it pays to calcine them, as it renders them more easily reducible, and it is found much more economical to effect this part of the smelting process outside the blast furnace by the waste gases from

it, than inside the furnace, at the expense of the more costly solid combustible.

Amongst the ores of the Lake Superior district, besides the magnetic and specular oxides of iron, are large deposits of hydrated oxides or brown hematites, some of them manganiferous. These ores are principally consumed in the blast furnaces of the Mahoning Valley, in Ohio; the Chenango Valley, in Pennsylvania; at Pittsburgh, Buffalo, Cleveland, Massillon, Dover, Toledo, Detroit, and Brazil; the ironmasters of Northern Ohio and Western Pennsylvania having by experience found it more advantageous to employ the pure rich ores brought from a distance, than the lean and less pure ores from the immediate neighbourhood of their own furnaces. At Buffalo, these ores are smelted with anthracite from Pittston; at Pittsburgh, with coke made from the coal of the vicinity, or from Connellsville, some sixty miles distant; whilst at Cleveland, coke from the Pittsburgh district is employed. In the Mahoning and Chenango Valleys, the coal is used in the raw state, as also at Brazil; whilst at Toledo and Detroit, charcoal is largely consumed.

The make of pig iron in the Lake Superior district, in 1871, is given at 51,225 tons, as compared with 49,298 tons in 1870; 39,003 tons in 1869, and 38,246, in 1868; whilst the value of the iron ores and pig iron taken together, is stated at 6,115,895 dollars in 1871, as compared with 2,405,960 in 1866; 419,501 in 1861, and in 1856 only 28,000 dollars, from which figures, an idea may be formed of the rate at which the iron industry in this district has progressed during the last quarter of a century.

In Pennsylvania, the extension of operations are equally as remarkable in the finished iron trade as in the production of pig iron. All the mills are in great activity, especially around Pittsburgh, where the rolling mills exclusively engaged in making bar and hoop iron (not including rails, plate, sheet, or nails) occupy 609 puddling furnaces, whilst the Chenango Valley employ 135 more. A new company, entitled the De Graaf Iron Works, have purchased the Laurence Iron Works, at Newcastle, which contain 17 puddling and 4 heating furnaces, as well as the extensive rail mill, belonging to Messrs. Dithridge & Co., of Pittsburgh. At the Onondago Works, Newcastle, 8 puddling furnaces and a nail works are being erected; a rolling mill, with 3 trains of rolls, is in course of construction at Milton, by the Milton Iron Co., and Messrs. Lyon,

Short, & Co., have put up a double puddling furnace. It may also be mentioned that the rolling mill belonging to Messrs. Harbaugh, Mathias, & Owens, at Pittsburgh, with 10 heating furnaces, turned out 36,336 tons of rails in the course of 1871, and no less than 1,115 tons in one week in the month of December last.

The St. Charles Iron Company has recently been established in Pennsylvania, with a capital of 1,000,000 dollars, in shares of 7 dollars each, for the purpose of erecting ten blast furnaces at Reading, each furnace being calculated to turn out 11,000 tons per annum. The cost of the ore delivered at the furnaces is estimated at 3 dollars per ton, and the cost price of the pig on the works at 20 dollars per ton, so that according to American prices, there should be a large margin for profit.

In Ohio, the manufacture is making rapid strides; Cleveland now has fourteen rolling mills, with 200 puddling furnaces, which are capable of turning out 400 tons of finished iron per day. At Columbus, large works have been erected; a new company has started the Bellaire Rail Mill, with fourteen puddling furnaces and three heating furnaces, and propose adding two more puddling furnaces and one blast furnace.

The Stebensville Furnace and Iron Company has lately been incorporated, with a capital of 300,000 dollars, in shares of 100 dollars each; and the Union Iron Company are building a blast furnace at Newbergen.

A British company, called the Glasgow Port Washington Iron and Coal Company, limited, with a capital of £250,000, in 25,000 shares of £10 each, has recently been formed for acquiring some 860 acres of freehold land, and working the deposits of black band ironstone and coal under the same, the former of which are estimated to contain 2,595,820 tons of iron ore, along with beds of fire clay and workable coal, five seams of which are stated to be from 2½ to 8 feet in thickness. This property, known as the Port Washington estate, is situated in the county of Tuscarawas, in Ohio, and is in the immediate vicinity of the Ohio State Canal, and the Pittsburgh, Cincinnati, and St. Louis Railway. Operations have already been commenced, and blast furnaces are being erected, it being estimated that the ironstone on these properties will supply two blast furnaces for forty years.

At Ironton, the Ohio and Pine Grove furnaces have been blown

out, and will not resume work before May. In the Mahoning Valley there are now six mills, containing 149 puddling furnaces.

In Illinois, the rolling mills at Chicago fortunately escaped the fire, and are in active operation.

In Missouri, the consumption of Iron Mountain ore has increased so largely that the extraction for this year is estimated by Mr. Chouteaux at 350,000 tons; this State contains three rolling mills, all situated at or near St. Louis.

The entire production of rails in the United States during 1871 is estimated at about 750,000 tons. No estimate of the quantity of plates has been received, although it is stated to be very large.

The attempt to manufacture steel from the iron sand of the beach having proved a complete failure, the machinery and fixtures of the steel works opposite West Hampton have been sold.

In February, two lectures were delivered at the Stevens Institute, Hoboden, New Jersey, by Mr. A. L. Holley, on respectively Bessemer machinery and modern rolling machinery.

B METALLURGICAL TECHNOLOGY.

Internal Structure of Iron.—It has long been known that the arrangement of the particles in a mass of iron may be rendered visible to the eye by treating a smooth surface of the iron with any acid solution which etches or acts unequally on the different parts of it. Advantage has recently been taken of this property, by Mr. Von Ruth, inspector of iron to the Dutch Government, as a means of recording, or rather depicting, on paper, the structure of any kind of wrought iron. He proceeds as follows:—The sample of iron in question, such as, for example, the section of a rail having been brought to a uniform smooth surface, by planing or otherwise, is acted upon by hydrochloric acid for from six to twenty-four hours, according to the nature of the iron, and the strength or temperature of the acid employed; so treated, the surface of the iron presents the appearance of an etched plate, the lines on which show the direction and arrangements of the fibres or grain of the iron. After this has been well washed with water, to remove all superfluous acid, and dried, an engraving can be printed from it with printing ink in the usual manner; or it may be employed as a die, placing a sheet of ordinary carbon paper, such as is used in

manifold writing, between it and the white sheet on which the impression is to be depicted. If a few sheets of writing paper are placed beneath this, to act as a pad, an ordinary letter copying press may be employed, when, upon removing the pressure, a good sharp picture is obtained on the white paper, which shows the details of the fibrous or granular structure of the iron in a very clear and distinct manner. The application of this simple and quick process as a means of studying the structure of iron in general, the formation of the pile in a rail, or the alteration of the fibre of the iron in the vicinity of a weld is likely to be found of much service.

Crystallized and Burnt Iron.—It has often been observed that even the most fibrous iron, when long exposed to vibration or concussion, is liable to change the internal structure of its component particles, and become granular or crystalline, so as ultimately to snap or break off suddenly. This is very commonly found to be the case with the pump rods in mines, but it is probably less generally known that, in many instances, this change has been observed to be attended with a strong development of magnetism in the iron. A mine foreman in Germany declares that he always knew when a pump rod was about to break, when upon holding his iron miner's lamp near it, it was attracted and held up by the pump rod, as it was then, in his opinion, high time to replace it before it actually snapped.

In the Comptes-rendus des Scéances de l'Académie des Sciences, No. 10, for the 4th March, 1872, M. Caron brought forward a communication "On Crystallized or Burnt Iron," a subject which of late has also been written upon here in England with results which appear different from those obtained by M. Caron. After explaining that the name of "burnt" iron is applied to iron which (although previously of a good, strong, and fibrous quality) after having been suddenly heated to a white heat, and allowed to cool in the air without being hammered, is found to have become brittle, both when tested hot as well as cold, and to present a strongly developed crystalline fracture, he combats the generally received opinion that these alterations in the iron are produced by its having absorbed oxygen, declaring that this view is not supported by his chemical analyses, which have not shown any appreciable difference in the constituents of "burnt," as compared with good iron. Direct experiments were consequently made by M. Caron, as follows:—A

bar of Franche-Comté iron, which was proved by all the ordinary tests to be of a good and fibrous quality, was cut into a number of pieces; some of these were heated suddenly to a white heat in a smith's forge; others were placed in porcelain tubes, and submitted to the action of currents of respectively hydrogen and nitrogen gases, when heated to as near as possible the same high temperature as those heated in the smith's forge. After having been allowed to cool under similar conditions, all these pieces, without exception, when broken across, showed the crystalline fracture of "burnt" iron, and whether treated hot or cold, had apparently the same behaviour; consequently as "burnt" iron can be produced at pleasure in either oxidising, neutral, or reducing atmospheres, it must be admitted, according to M. Caron, that this change cannot be dependent on the absorption of any gas in particular, but that it is simply due to the action which the heat has in altering the molecular arrangement of its particles. Again, M. Caron does not admit that iron becomes brittle, and liable to break after having been exposed to vibration, and declares that the idea that iron becomes crystalline, and more liable to fracture under the influence of cold in winter, is not tenable, and considers the following experiments as proving this not to be the case. Several pieces of the same bar of iron, before referred to, were exposed in the freezing works of M. Tellier, at Auteil, to temperatures varying from the freezing point of water, down to about the zero of Fahrenheit's thermometer, for more than four months; whilst others remained out in the air during last winter, when the frost was so severe that the thermometer even showed as low as 4° below zero (Fahrenheit). Attempts were made to break these bars, both when cold, and when at a temperature of a few degrees above the freezing point of water, but in no instance were they found to have become brittle or crystalline, or to differ in strength from that of the original bar. M. Caron adds that all his experiments were made upon iron of undoubtedly good quality, and that he is not prepared to deny that it may not be otherwise with inferior iron, and that it is not improbable that iron of bad quality or workmanship may become perceptibly more brittle under the influence of low temperature. From the results of his experimental inquiry into the subject, he arrives at the conclusion that in all instances in which bars of iron break under impact, showing a crystalline fracture, it is certain that this

crystalline structure pre-existed in the bar, and was generally due to bad workmanship, but never was brought about by the effects either of the actual strain or degree of cold to which the iron may have been exposed after having once been manufactured.

Direct Reduction of Iron from the Ore.—A patent has been obtained by Mr. T. S. Blair, of Pittsburgh, Pennsylvania, U.S., for reducing, to the metallic condition, finely pulverized iron ores, by currents or jets of deoxidating gases, which at the same time propel the ore along the inclined bed of the furnace. The powdered ore is delivered from a sort of hopper at the upper end of the sloping hearth of a heated chamber or furnace, into which, oblique openings admit currents of gas being forced in.

Superheated Blast.—The temperature of the air employed in smelting iron ores with charcoal on the Continent seldom exceeds from 600 to 700 degrees Fahrenheit. In Austria, however, recent accounts from the Steyrmarck district report that the employment of hot blast of about double this temperature (1,200° Fahrenheit) has been attended with much superior results in the charcoal furnaces. In the manufacture of speigeleisen, a decided improvement in the smelting, especially as regards the amount of manganese reduced into the metal, is found to result from the use of an extremely hot blast.

Pyrometers.—Mr. Robert Spencer, of New York, has recently patented making pyrometers with bulbs of iridium, enclosed in a casing or "brick," composed of a mixture of one part washed ganister, three of purified fire-clay, and one of pulverized calcined pots. No detailed description of the instruments themselves, or their working performance has, up to date, been received.

Employment of Quick Lime in Blast Furnaces.—In the Annales des Mines, Ser. vi., Vol. XX., pp. 525-546, M. Grüner, professor of metallurgy in the School of Mines at Paris, communicates a somewhat detailed paper on the use of quick lime in blast furnaces, and on the employment of Hoffmann's annular kiln for burning the limestone. It is well known that quick lime has, since 1850, been employed, and is so at present, in many of the blast furnaces in England and Wales, as well as in Silesia and Belgium; but it does not appear to have met with that universal acceptance which it merits, principally for the reasons, according to Professor Gruner, that too little attention has hitherto been paid

to the subject of its economical preparation, and to preventing the lime when once burnt from absorbing carbonic acid and water in the blast furnace itself, the first of which conditions is considered by the professor to be obtained by the use of Hoffmann's annular kiln, which he also recommends for the calcination of hydrated ores and carbonates of iron, as well as for burning fire-bricks; whilst the second, even if it is not possible to avoid altogether, can, he thinks, at least be much diminished.

In a limekiln, in which the carbon of the fuel is entirely converted into carbonic acid, it requires, according to Professor Grüner, a consumption of only 4·6 kilogrammes (10·14 lbs. avoirdupois) pure carbon to decompose or burn into quicklime 100 kilogrammes (220·4 lbs.) limestone, whilst in a blast furnace, owing to the carbon being transformed only into carbonic oxide, it requires no less than 15·1 kilogrammes (33·29 lbs.) to produce the same effect, even without taking into consideration that the escaping gases from a blast furnace carry off in proportion more heat than from a limekiln; in addition to which, owing to the specific heat of the gases, the 44 kilogrammes (97 lbs.) carbonic acid in this quantity of limestone, will only require 0·36 kilogrammes (0·79 lbs.) carbon against 1·17 kilogrammes (2·57 lbs.) in the blast furnace. So that the decomposition of the carbonate of lime in 100 kilogrammes limestone, in conjunction with the heating up of the gases will necessitate a consumption of 16·27 kilogrammes (35·86 lbs.) in the blast furnace, instead of only 4·96 kilogrammes (10·93 lbs.) in the limekiln; and when it is remembered that some 600 kilogrammes (1,322 lbs.) of limestone are used as a flux, in coke blast furnaces, to every ton of pig iron produced, the difference will be as 29·76 kilogs. (65·58 lbs.) per ton when the limestone is burnt outside the furnace, as compared to 97·62 kilogs. (214·16 lbs.) when it is charged into it in the raw state. Independent of this direct loss occasioned by using limestone, a further indirect increase in the consumption of fuel arises from the carbonic acid, which has been expelled from the limestone in the lower or hotter zone of the furnace, taking up carbon as it ascends to the top, thereby reducing itself to carbonic oxide at the expense of the fuel in the furnace, and, although Professor Grüner does not admit the correctness of Mr. Lowthian Bell's view that the entire quantity of carbonic acid in the flux is sent out of the furnace in the form of carbonic oxide, still,

admitting that even as little as only one-quarter escapes in this condition, this would entail a still further consumption of 18 kilogs. (39·67 lbs.) carbon to the ton of pig iron produced, in addition to 22 kilos. (49·51 lbs.) for the absorption of heat, which must be restored to the blast furnace, or in all 40 kilos. (89·18 lbs.) per ton of iron, even when it is supposed that only one-fourth of the carbonic acid in the limestone has been reduced to carbonic oxide before passing off into the air; now if this amount be added to the 97·62 kilos. (214·16 lbs.) previously obtained, we have a total of 147·62 kilos. (303·34 lbs.) of carbon consumed, when limestone is used against only 29·76 kilos. (65·58 lbs.) required, when quicklime is substituted, or a clear gain of at least 107·86 kilos. (257·76 lbs.) pure carbon, or something like two and a half cwts. of coke per ton of pig iron made, or about ten per cent. of the entire amount of the coke consumed in smelting the iron ore. In actual practice, Mr. Lowthian Bell only finds a saving of three quarters of a cwt. per ton of pig iron, which would be about 3½ per cent., or but little over a third of what has been estimated above, and this difference appears to be due in part to the imperfect burning of the lime, and more particularly to the presence of carbonic acid and watery vapour in the upper zone of the blast furnace; and, as a remedy, it is considered by Professor Grüner that the employment of dry calcined ore, dry coke, and fresh very strongly burnt lime, preferably somewhat aluminous or magnesian, will tend to bring the results of practice more approximating to those of theory.

For a description of the annular kiln of Hoffmann's construction, we must refer to the paper itself, but may mention that Professor Grüner states that one of these kilns, which in France costs at highest £1,000, is sufficient to supply the lime (25 tons per day) required as a flux for a blast furnace turning out forty tons of pig iron per day, and calculates that it would effect a saving of at least one franc per ton on the iron made, as the amount of inferior coal slack required would not exceed from 6 to 7 per cent. of the weight of the limestone burnt.

UTILISATION OF BLAST FURNACE GASES.—A patent has been lately taken out by M. J. De Langlade for improvements on the utilisation of the gases from blast furnaces employed in smelting iron ores; they consist principally in washing and purifying the gases first, and then sending them through a regenerative apparatus,

the pressure of the gases being regulated by a special arrangement so as to enable them to be supplied at a constant and uniform rate for burning in reverbatory furnaces, or for other heating purposes.

Utilisation of Blast Furnace Slag.—In order to adapt the slag to such purposes as ballasting for railways, road metal, &c., the blast furnace slag at the George-Marie furnaces at Osnabruck, in Hanover, is allowed to flow from a height of eight feet into water, the effect of which is to convert it into large bean-shaped gravel; as fast as this is formed, it is lifted out of the water by an endless chain of buckets, which load it directly on to the railway trucks.

Bessemer Converters.—Mr. Henry Chisholm, of Cleveland, Ohio, U.S., has patented improvement in steel converting vessels, amongst which may be mentioned, attaching the lower part of the converter so that its surface or face along the top of the tuyeres forms a plane in line with the base and lining; also forming the joints of the sections of which the converter is composed, so that the lining shall be prevented from adhering to the bed of the vessel, when the sections require to be separated from one another, yet at the same time ensure a close joint when they are put together.

Bessemer Steel for Artillery.—Experiments are now being carried on at Neuberg, in Steyermarck, Austria, with a view to the employment of this class of steel for artillery purposes. When casting, the molten steel is, by means of hydraulic power, subjected to a pressure of 350 tons, the effect of which is to cause the air holes or pores in the external parts of the mass of steel to move towards and accumulate in the centre of the casting, where they do not effect the strength of the cannon, since they are eliminated in the act of boring out its calibre.

Silicon Steel.—The process for making this description of steel, which was briefly noticed in the last quarterly report, has since been also patented in this country by its inventor, Charles Motier Nes, of New York; the pig iron from which it is made is ordered to be melted in a suitable furnace, and when nearly melted, an addition of from fifteen to forty per cent. of its weight of silicious magnetic iron ore, mixed with coke, is made, and well stirred into the metal, after which, it is run out into pots placed at the side of the furnace, holding about half a ton each, in which, it is well stirred up with a rabble, previous to being tapped into

the moulds. If wrought silicon steel is required, the same process is followed out, with only the difference, that when the steel is in the pots, it is stirred up until it "balls up," or comes to nature, as it is termed. Silicon steel, when of good quality, is stated to contain 0·600 per cent. carbon, along with 0·552 per cent. silicon.

Cast Steel.—A patent has been taken out by Mr. H. C. Bosse, of Quebec, for treating pulverised iron ores, or metallic iron, in the form of fragments, clippings, or sponge, with an admixture of powdered graphite, anthracite, charcoal, coal, or coke, in definite proportions, in a Siemens regenerative, or other furnace heated by gas, so as to produce cast steel of any desired quality, at one operation. The materials must be free from all impurity, and in a state of fine powder; if melted in a furnace, the charge may, if necessary, be covered with a flux of glass, or blast furnace slag, free from sulphur, or with slabs of soapstone, tiles, &c., but no covering is said to be required when gas furnaces are employed in which a neutral flame can be obtained. It is not very apparent, where the novelty or improvement in this invention consists.

Crucibles for Cast Steel.—A peculiar variety of clay, to which the name of Wocheinite has been applied, from the place Wocheina, in Carinthia, Austria, at which it is found, promises to be a valuable material for the manufacture of crucibles, and other refractory ware, owing to its containing as much as 50·82 per cent. of alumina. Not being sufficiently plastic, it requires the addition of other clay, in order to enable its being easily moulded, and Dr. Schwarz reports that crucibles, made of this mineral, mixed with from one quarter to one half its weight of fire-clay, gave very good results.

Melting Steel in Large Quantities.—Instead of crucibles, Von Carnac employs for melting large quantities up to as much as a ton of steel at a time, a reverbatory furnace, with blast below the fire-grate; the body of the furnace itself is so long that the steel can be placed and heated at the end nearest the flue which leads to the chimney, before coming into the actual melting compartment; to the steel a quantity of broken glass or clean charcoal blast furnace slag is added, so as to form a flux or bath, standing about one or two inches thick above the molten steel; care must be taken that the glass employed has not been made with sulphate of soda, in order to prevent sulphur being given up to injure the quality of the steel.

Solid Castings.—The invention of Mr. J. B. Tarr, of Fairhaven, Massachusetts, U.S., is stated to be an arrangement by which a plunger driven upwards by a hydraulic press enters the mould containing the molten metal, and exerts a considerable pressure upon it; the principal appears to be the same as that long employed by Whitworth, in Manchester, although the details differ considerably.

Puddling by Petroleum.—According to the Pittsburgh commercial paper, and some French technical periodicals, petroleum is stated to have been successfully employed as fuel in puddling iron at the works of Laclède, of St. Louis, Missouri, U.S., for the last three months; the experiments are said to have been conducted by reliable and practical men, to have been made under varying conditions, and the iron produced tested in every way to prove its quality; the general results are stated to indicate that petroleum is the best fuel hitherto employed in puddling, both in respect to convenience, efficiency, and the superior quality of the iron produced. As no mention, however, is made of the expense attendant on its use, it is to be feared that on the score of economy, petroleum is not likely to recommend itself to the trade.

Rotary Puddling Furnaces.—This system of mechanical puddling, which seems destined very shortly to replace all the present hand furnaces, has, owing no doubt to the higher rate of wages and the greater difficulty found in obtaining a full supply of skilled labour, attracted much more attention in the United States of America than has been accorded to it here in Great Britain. Full details of the Danks furnace, with its machinery and the results of its working in the United States have already appeared in the Journal of the Institute, and since then, its introduction into this country has been attended with the most complete success. It remains, however, to mention, that within the last few months patents have been granted in the United States for two other arrangements for rotary puddling furnaces to, respectively, Mr. William Sellers, of Philadelphia, and Mr. William Baynton, a manager of a rolling mill at Pottsville, in Pennsylvania. As a description of both these inventions has already been published in the *Iron and Coal Trades Review*, for April 24th, 1872, p. 327, which contains the specification of Mr. Baynton in full, we would refer to that Journal for a more extended account of these inven-

tions than the space still at disposal in the present report will allow.

Action of Carbonic Acid on Metallic Iron.—M. Tissandier, in the Compt. Rendus. LXXIV., p. 531, communicates experimental researches on this subject, showing, when carbonic acid gas comes in contact with metallic iron at a red heat, that the acid is decomposed, and protoxide of iron is formed at the expense of one of the equivalents of oxygen in the gas, thereby reducing it to the state of carbonic oxide which escapes; this reaction is important in considering questions connected with the metallurgy of iron, and is proposed as a means for obtaining anhydrous protoxide of iron. The oxide thus prepared is black, brilliant, and crystalline, as well as magnetic; when heated to redness in contact with air it absorbs oxygen, and is converted into the red sesquioxide of iron.

Assay of Iron Ores.—A paper by Mr. T. M. Blossom, of the School of Mines, Columbia College, New York, on this subject, is reproduced in the *Chemical News* of the 5th April, 1872, from the American Chemist.

April 25th, 1872,
11, York Place, Portman Square, London, W.

NOTICES OF BOOKS.

Chemical Phenomena of Iron Smelting. By I. Lowthian Bell. London: George Routledge and Sons, & E. & F. N. Spon: p.p. 436.

It is only necessary to allude to this work very briefly, as the matter which it contains has already appeared in the Journal of the Institute. In the preface, the author gives a short sketch of the improvements that have taken place since 1846 in the mode of smelting iron in the North of England. In 1846, the firm with which Mr. Bell is connected erected the first furnace intended for the smelting of Cleveland ironstone. This had a capacity of about 3,500 cubic feet, and the ore was obtained from the neighbourhood of Whitby. The Witton Park furnaces of Messrs. Bolckow and Vaughan were built a few years later, but these were only 2,850 feet in cubic capacity. In 1850, ironstone, obtained from the Eston Hills, was first smelted at Witton Park, and in consequence of the favourable yield, three furnaces were, in 1851, erected at Middlesbrough, the cubic capacity of each being 4,566 feet. These were followed the next year by two others, built by Messrs. Gilkes, Wilson, Pease and Co., with a capacity of 5,100 cubic feet. There was nothing in the consumption of fuel at any of these furnaces to indicate any advantage over the Wylam furnace of little more than half the size. In 1854, Messrs. Bell Bros. blew in three furnaces, at Clarence, the capacity of each being, 6,174 cubic feet. Up to that time, the utilisation of the escaping gases had not been practically carried out; but this was accomplished at these furnaces, the result being a considerable reduction in the consumption of coke. No material improvement in the saving of fuel was effected in the numerous furnaces erected up to the year 1861, when Messrs. Whitwell put up their three Thornaby furnaces, having boshes 20 feet in diameter, and a cubic capacity of 12,778 feet per furnace.

The consumption of coke in these furnaces was found to average about 25 cwts. to the ton of iron, being about 5 cwt. below the working of the majority of the furnaces in the locality. In 1862, the late Mr. Vaughan erected a furnace 75 feet in height, though it was not equal in cubic capacity to those of Messrs. Whitwell. The results obtained by this change in dimensions were so favourable that, before long, blast furnaces of vastly increased cubic capacity, and varying in height from 70 to 103 feet, were erected. In 1868, enquiries began to arise as to the extent to which an increase in the dimensions of blast furnaces might be economically carried. Mr. Charles Cochrane maintained that enough heat might be conveyed into the furnaces in the hot blast to enable a ton of Cleveland iron to be produced with 13 cwts. of coke, as against 22½ cwts., the general average of the district at that time. The author of this treatise, on the other hand, held different views; and in order to put these to the test, he commenced an elaborate series of experiments for the purpose of determining, if possible, the nature of the reactions which take place among the substances dealt with in the manufacture of pig iron. The nature of those experiments is fully set forth in the book under notice, and the conclusions at which the author arrives are, in effect, that no economy in fuel is to be expected by the use of furnaces of extreme dimensions; but that with a cubic capacity of about 18,000 feet, and a height of about 80 feet, if pig iron can be made from Cleveland ironstone with 21½ cwts. of coke per ton of iron, the theoretical limits of economical working will be nearly reached.

THE METALLURGY OF IRON. BY H. BAUERMAN. Third edition, London: Lockwood & Co.

This is a useful handbook, giving in a comparatively small compass a large amount of information bearing upon the metallurgy of iron and steel. In this edition, which has been recently published, the later improvements in iron and steel making are introduced. This work is caluclated to be of great service to those who have not time to consult the more elaborate treatises of Percy, Crookes, and other well-known writers on this subject; and the matter contained in it appears to be throughout of a thoroughly trustworthy character.

Geological Survey of Ohio: Report of progress in 1870. Columbus, Nevins and Myers.

This volume of nearly 600 pages, amply illustrated by maps and sections, contains a general outline of the progress made by the State Geological Survey of Ohio, up to end of 1870. The survey in question appears to consist of eight geologists and one chemist, and though at the date of this report they had only been at work for nineteen months, it is quite evident that they have collected a vast amount of information, and that they are making the survey with special reference to its bearing upon the development of the industrial resources of the State. The chief geologist, in his report, states that particular attention is being devoted by two of the staff to the collection of all facts bearing upon the iron manufacture. In their final report, it is proposed to give tabulated descriptions of the dimensions, capacity, production, &c., of the furnaces in blast in the State. The report under notice contains sketches of the present state of the iron and steel manufacture in the principal localities; two members of the staff have also been to Europe, for the purpose of making themselves acquainted with the methods adopted in the principal seats of the iron trade there. We notice this report principally because it indicates what valuable work may be done even by a small but well-directed staff, when the object is to conduct a geological survey with the view of affording as much assistance as possible to those who are engaged in developing the mineral resources of a country. The State of Ohio is about 250 miles by 230 miles in extent, and yet the head of the geological staff, who has only been at work for less than a couple of years, promises the legislature that he will, in the session of 1871, present the first volume of his final report. Time has also been found to send a deputation to Europe.

PROCEEDINGS OF SCIENTIFIC AND TECHNICAL SOCIETIES.

Economy of Fuel in the Blast Furnace.—At a meeting of the Institute of Civil Engineers, held on March 19th, a paper was read "On the Conditions which Favour and those which Limit the Economy of Fuel in the Blast Furnace in Smelting Iron," by Mr. I. Lowthian Bell. The following is an abstract:—

During the last session of the Institution, an account of two blast furnaces, then recently erected at Newport, near Middlesbrough, was given by Mr. B. Samuelson, M.P. In the discussion upon that communication, the author of the present memoir held that, after certain dimensions of a furnace were attained, no further advantage from subsequent enlargement was possible, so far as fuel consumption was concerned. This condition was based on there being, according to his views, an actual evolution of heat near the throat of the furnace, which maintained a tolerable constancy of temperature in the escaping gases; and also that, as soon as sufficient time had been afforded to permit the requisite saturation of those gases with oxygen, no good could arise from their further retention among the materials. This latter condition likewise involved the useful limit to high temperatures in the blast, for it would be shown that any increase of energy in the reducing power of the gases, acquired by a greater intensity of heat, was neutralised by a corresponding loss of fuel. In opposition to these views it was alleged, that no such heat evolution as had been referred to took place in the upper zone; that there existed no limit whatever to a useful increase in the temperature of the blast; and that furnaces might still be profitably enlarged, provided some modification of form was introduced.

The subject of economising fuel, in a process consuming nearly one-sixth of all the coal raised in the empire, justly excited much

attention; but as this branch of the question was only incidentally brought forward on the previous occasion, the author now proposed to deal exclusively with the working of the apparatus. When a scientific metallurgist approached the enquiry of fuel consumption in the production of pig iron, he must first satisfy himself in respect to the quantity of heat absorbed in the process, and then, by estimating the calorific power of the fuel, he must determine the weight of combustible necessary to afford the required effect. The real difficulty in the calculation did not consist in ascertaining the actual quantity of heat necessary for the process, but in determining the proportion of the fuel that could be converted into carbonic acid and into carbonic oxide respectively, as there was an evolution of 8,000 heat units, centigrade scale, for one unit of carbon, in the former case, and of only 2,400 in the latter. Assuming that the ore yielded 40 per cent. of pig iron, and required 15 cwt. of limestone as a flux, then the heat absorption per ton of metal in the four divisions of the furnace was, in the zone of fusion 34,900 units, in the zone of heat interception 2,500 units, in the zone of limestone decomposition 11,310 units, and in the zone of reduction and carbon impregnation 35,490 units, to which must be added for loss in the escaping gases 8,800 units, making a total of 93,000 units. To ascertain the actual quantity of coke required to produce a ton of iron under the circumstances described, there must be deducted, from the total number of heat units absorbed, otherwise than those derived from the combustion of the fuel, say 38,000, leaving to be supplied by coke 55,000 cwt. heat units, which, divided by 2,400, gave their equivalent in pure carbon to be equal to 22·9 cwt., and the carbon absorbed by the iron being 0·6 cwt., there remained a total of 23·5 cwt. of pure carbon, which was equal to about 25½ cwt. of ordinary Durham coke.

It required but a moderate acquaintance with the simpler laws of heat and chemical action to realise some of the conditions which regulated the action of the blast furnace. In the lowest zone the act of fusion and its accompanying decompositions might be said, as a matter of speed, to be regulated by the rapidity with which the carbon was oxidised, and this, for all practical purposes, was settled by the rate at which the blast was injected at the tuyeres. It was widely different with the interception of heat,

which required time for its accomplishment; hence, if the furnace was too low, the ascending gases would not have time to communicate their sensible heat to the descending solids, and the latter would, in consequence, arrive at so low a temperature at the tuyeres as to demand an addition to the fuel which had to liquify the metal and slag. These considerations involved the question of the height of the blast furnace, and the quantity of work it was capable of performing. The dimensions which would enable an iron smelter to produce a ton of metal with 25½ cwt. of coke burnt with cold blast, from ordinary clay ironstone, were at present to some extent a matter of speculation. At Lilleshall, however, foundry iron was now obtained at an expenditure of 27½ cwt. (in place of 40 cwt.) with cold air, from the ordinary ironstone of the coal measures, yielding a trifle above 40 per cent. Furnaces able to produce a ton of pig iron, under the circumstances described, with from 27 to 28 cwt. of coke, had not been in use more than nine years, prior to which they rarely exceeded 50 feet in height, with a capacity of 6,000 or 7,000 cubic feet. In considering the nature of the change of action which would suffice to account for so marked an economy in the quantity of combustible required to produce the same result, as a reduction from 40 to 27½ cwt., it was necessary to keep in view a few of the facts connected with the action of the oxides of carbon on the iron oxides, as well as on the metal itself. These were explained; and it was stated that they had been the subject of a lengthened experimental research, the results of which were embodied in an article on the "Chemical Phenomena of Iron Smelting," published in the "Journal of the Iron and Steel Institute." The mode of avoiding the loss from the decomposition of the carbonic acid, generated by the reduction of the oxide of iron, was to secure the latter operation being performed under circumstances where the temperature was elevated enough to deoxidize the ore, but was not sufficiently intense to have the resulting carbonic acid split up by carbon. This was secured by removing the region, in which reduction and also carbon impregnation took place, to a sufficient distance from the zone in which the materials were too intensely heated by the ascending gases.

The position of what might be designated a perfect form of furnace had been thus far considered, without reference to the progress of events, or the order of improvement which led to its

adoption. It was not so, however, in the year 1827, when a height of furnace of 50 feet, with a capacity of from 4,000 to 6,000 cubic feet, fulfilled all the requirements deemed necessary by the iron smelter. About the year named, the late Mr. J. B. Neilson conceived the idea, that by heating the air before it entered the blast furnace, an increased intensity of temperature would ensue. At the period of its introduction, the "hot blast" constituted one of the most remarkable events in the history of the iron trade. Before attempting to point out what the author believed to afford the true explanation of the theory of the hot blast, he directed attention to one or two circumstances in connection with its applications which, in his opinion, had been too little considered by those who had examined the subject. Thus, in treating Scotch black band, for every ton of iron made there was produced about half-a-ton of slag; so that in the hearth there had to be fused 30 cwt. of material, effected, in the days of cold blast, with 60 cwt. of coke. In Wales, and in some parts of England, the weight of slag was about 30 cwt. to the ton of iron, giving 50 cwt. to be melted at the tuyeres; and this was done with cold air with 40 cwt. of coke. In France, M. Dufrenoy mentioned cases where 20 cwt. of iron and 30 cwt. of slag were fused with 25 cwt. of fuel, the air used being cold. Equally disregarded, as a matter of argument, had been the great difference of effect produced by the application of hot blast in the three instances quoted. In Scotland, raw coal took the place of coke; but there was little doubt, were coke still employed, 30 cwt. would be amply sufficient with hot blast to do the work of 60 cwt. when cold air was used, giving 30 cwt. as the saving of furnace fuel. In England and Wales, for the cases given, 10 to 12 cwt. of coke was all the economy realised by the change from cold to hot air; and in France, upon the occasion alluded to by M. Dufrènoy, the saving, if any, was so unappreciable, that he reported the results there to be "unfavourable to the use of hot air."

The law which, the Author believed, determined the weight of fuel required to smelt ores of different kinds, and which constituted the value of the hot blast, was, that the rate of reduction should not proceed less rapidly than that of fusion. When a furnace was driven with cold air and was of inadequate height, it had been shown that there was a loss of fuel; and this was explained by the

fact, that the reducing gases escaped before they had absorbed all the oxygen they were capable of holding, and before they had divested themselves sufficiently of the sensible heat they contained. To retard fusion of a given quantity of iron and slag, less ore and flux were given to be melted; and thus, in a furnace of inferior dimensions, the two functions were brought into harmony, of course at an expenditure of fuel. It by no means, however, followed that the quantity of fuel required to bring these two operations, fusion and reduction, into unison was the same in every case. In ores of similar richness this would be so, did the oxide of iron they contained yield its oxygen with equal facility. This, the Author had convinced himself, was far from being the case; and hence it need only be supposed that the Scotch black band was one-half longer time, or thereabouts, in surrendering its oxygen than another ore, to be satisfied that it was necessary to retain it one half longer time in contact with the reducing gases. It had been demonstrated at the Clarence Iron Works, by many weeks' experience, that reducing the speed at which a furnace was driven was productive of no benefit, from the escaping gases rising in temperature. Time, then, was the element which was required to make amends for the want of readiness with which a particular ore parted with its oxygen, but this was not the only disposable means, for the same result could be secured by a very moderate alteration of temperature. Thus, calcined Cleveland stone at 410° Cent. (770° Fahr.) lost 37 per cent. of its oxygen; but when the heat was raised to that of dull redness, it was deprived of nearly double that quantity, the time of exposure being the same in each case. That it was time alone which effected the change, and not any mysterious virtue in the heat of the blast, was proved by experience at Lilleshall; where, by heating the air of a 53-feet furnace, precisely the same result in point of economising fuel followed, as was obtained by raising the furnace to a height of 71 feet.

It had now been shown, that in the matter of fuel consumption, a 71-feet cold blast furnace worked as perfectly as one driven with heated air, and having an altitude of 53 feet. The latter, it was true, turned out a larger make of iron (probably 200 tons as against 120 tons per week); but the former, without any apparatus to maintain or fuel to expend for heating the air, was able to do its work as efficiently, in point of fuel consumed in the furnace.

There still remained to be considered the possibility of constructing a furnace so large as to dispense altogether with the use of hot air without any sacrifice of the fuel used in the furnace itself; and afterwards to examine the effect of uniting the benefit derived from a high temperature of blast with that obtained by enlarged capacity. The first portion of this inquiry had already been answered, by showing that a reduction of 12½ cwt. of coke was effected upon an ore only requiring, in a 53-feet furnace, 40 cwt. of this combustible. In the next place, supposing, into a furnace sufficiently large to enable the ascending gases to divest themselves of their sensible heat and to become saturated with oxygen, instead of cold air, the blast was admitted at a temperature of 932° Fahrenheit, then the same effect in point of increase of intensity would follow, as happened when the blast was changed from cold to hot in the lesser furnace; and some of the extraordinary consequences, supposed to be due to this additional intensity of the heat in the hearth should manifest themselves, if the value of the hot blast were dependent thereon. Such, however, was not the fact, for the furnace having now sufficient capacity to permit the two functions of fusion and reduction to proceed in point of time in unison with each other, instead of one heat unit in the blast doing the work of three or four previously evolved by the fuel, each unit of heat thrown in with the air did no more duty than one unit produced by the combustion of coke in the inside of the furnace. With combustible matter of the same commercial value, it would no doubt be simpler to obtain the necessary heat by the direct action of the blast on the fuel in the hearth of the furnace. Inasmuch, however, as the air was now heated by the escaping gases, or by coal of little value, there was, in spite of the law just referred to, a notable advantage in the source of heat rendered available by Mr. Neilson's invention. The question, therefore, was the extent to which it could be substituted for that generated by the more expensive description of fuel used in the furnace. The chemical laws already alluded to, which regulated the power of carbonic oxide to deoxidize an ore of iron in presence of a gas having a contrary tendency, such as carbonic acid, imposed a limit to the substitution of mere heat for heat accompanied by the carbonic oxide, the generation of which served as its source. In treating the ironstone of Cleveland, if 25½ cwt. of coke, burnt

under favourable conditions, could smelt a ton of iron with cold air, 4 cwt. of such coke could be saved if into the furnace a quantity of heat could be introduced with the blast representing the 4 cwt. in question. Supposing, however, that instead of being content with the blast being heated just enough to afford an economy of 4 cwt., which would be about 905° Fahr., the temperature was raised to, say, 1,472° Fahr. This addition to the heat resources of the furnace would immediately be felt all over its contents, and as soon as it reached the zone of reduction, where the temperature was such, that the carbonic acid therein generated was inert on carbon, this condition of things experienced a complete change, and the superheated carbonic acid now dissolved coke, which was productive of loss, both from the cooling effect of the reaction and from the actual diminution of fuel arriving for combustion at the tuyeres. Actual experience demonstrated that excessive heat was simply wasted in the blast furnace to which it was applied. Where, however, mechanical difficulties prevented a particular kind of ore being treated in a sufficiently capacious furnace, the structural defect found, no doubt, a valuable remedy in superheated air. The results of repeated observation had shown, that a furnace 80 feet high, with a capacity of 12,000 cubic feet, emitted the gases as cool as one twice that size. Larger and larger dimensions were adopted in the North of England, until a capacity of 41,000 cubic feet had been reached, without, in the author's opinion, any commensurate advantage.

The question of obtaining a minimum temperature in the escaping gases, representing as it did in the largest furnaces 2 or 3 cwt. of coke, had been made the subject of direct experiment. This was performed by removing the calcined ironstone from the burden of a blast furnace, and replacing it with an equal weight of slag and flints upon which carbonic oxide was inert. The result was, as soon as the ironstone was taken off, the temperature fell, and only began to rise again when it was replaced, proving that the reduction of oxide of iron was accompanied by an evolution of heat.

The study of the conditions which determined the question of the quantity of fuel required to produce a ton of pig iron, was attended with considerable labour, and no inference could be drawn on the probable behaviour of one ore by observations on another. Indeed, the phenomena connected with the operations of the blast

furnace were liable to be affected by so many disturbing causes, that much caution was required to avoid arriving prematurely at any fixed opinions on the nature of a process so complicated as that of iron smelting.

Rivetting Tests.—The Transactions of the North of England Mining Institute contain a report upon experiments of rivetting with drilled and punched holes, and hand and power rivetting. It is stated that in the experiment made before the April meeting, the plate broke in the punched holes under a load of 18 tons, being 18 tons 2 cwts. per square inch of sectional area of plate, and 17 tons 9½ cwts. per square inch of rivet. In this joint the widest part of the punched hole was found to have been laid to the other plate, thus giving an inferior bearing for the rivet. The second experiment with the drilled seam, after having been subjected to the strain as above, did not carry the load of 15 tons, one plate being broken across and the other cracked at both sides. Though this was a double experiment, they are both noted in the table.

In experiments Nos. 3 to 8 inclusive, the strips were planed at the sides to about 2 inches wide, or the average pitch of the rivets in boiler work, and the holes were formed in the middle, care being taken to keep the drilled holes as nearly the same area as the punched holes as possible. AA and EE were drilled, BB and DD were punched, C1 and F1 were punched, and C2 and F2 were drilled, the former, C1, being left to be filled by the closing of the rivet, the latter, F1 receiving the shoulder of the rivet. No. 3 was begun with too great a load, and the rivet was sheared at once. The other five strips also gave way at the rivet, the greatest strain being 18 tons 14¾ cwts. borne alike by CC and DD. The least strain was 16 tons 6 cwts. per square inch of rivet, giving an average, on the five tests, of 17 tons 9 cwts. per square inch of section of rivet. The greatest load carried by the plate was 21 tons 6 cwts. per square inch, and also by CC and DD; the least, 18 tons 1¾ cwts., or giving the average of 19 tons 8¾ cwts. per square inch of sectional area of plate.

In the experiments 9, 10, 11, the plates broke through the rivet holes, the punched plate carrying 18 tons 12 cwts. strain per square inch. No. 11 is valuable as showing the relative value of holes that are not punched fairly, showing a considerable diminution of

strength. The average of the three experiments was 17 tons 16 cwts. as the ultimate strain per square inch of plate, and 15 tons 1¼ cwt. per square inch of rivet in sectional area, carried without fracture.

In experiments 17, 18, one rivet only was sheared in each, showing the average breaking strain of 17 tons 11 cwts. per square inch of sectional area of rivet and 18 tons 15½ cwts. per square inch as the strain on the plate.

The deductions from the above may be briefly summed up:—(1.) That punched holes have not been found to be inferior to drilled holes. (2.) That the breaking strain of the plate when new is greater than that of the rivet per square inch of sectional area; and (3) That the influence of bad workmanship upon the strength of a seam is more than is generally admitted, and as a rule drilled holes would be more accurate and less likely to overlap than punched ones.

ABSTRACT OF TABLE OF RIVETTING TESTS.

Maker.	Experiment.	Punched	Drilled.	Work.		Remarks.	Breaking Strain per Square Inch.	
							Plate.	Rivet.
Joicey	1	1·2	2·3	Single Lap.	Hand.	Broke in the punched holes	18·2	....
,,	2	....	2·3	,,	,,	Gave way at once, both plates fractured	15·1¾	....
,,	3	....	A A	,,	,,	Rivet sheared at once ..	....	23·6
,,	4	BB	....	,,	,,	Rivet sheared	....	16·19¾
,,	5	C 1	C 2	,,	,,	Rivet broken, C1 plate cracked ..	21·6	18·14¾
,,	6	D D	....	,,	,,	Rivet sheared, plate slightly cracked	21·6	18·14¾
,,	7	....	E E	,,	,,	Rivet sheared	....	16·6
,,	8	F 1	F 2	,,	,,	Rivet sheared	....	16·10
Boyd	9	C	....	,,	,,	Broken in rivet holes ..	18·12	....
,,	10	....	D	,,	,,	,, ,, ..	17·17	....
,,	11	E	....	,,	,,	,, ,, ..	16·19	....
,,	17	....	L	,,	,,	One rivet sheared ..	....	17·4⅔
,,	18	....	M	,,	Machine	,, ,, ..	....	17·17¼

RESULTS OF EXPERIMENTS WITH PUNCHED AND DRILLED SEAMS CLOSED BY HAND AND POWER.

Maker of Bar for Experiment.	Number of Experiment.	Rivet Holes.		Kind of Seam.		Sizes of Plates.		Rivets.		Sectional Area of Plate.		Testing Loads.			Breaking Strain per Square Inch.		Remarks.	Load borne per Sq. In. at time of fracture.	
		Punched.	Drilled.	How Laid.	Work.	No. 1.	No. 2.	Number.	Area.	No. 1 Plate	No. 2 Plate	First Load	Greatst borne.	Broke under.	Plate.	Rivet.	Result of Experiment.	Plate.	Rivet.
						Inches.	Inches.		Sq.in	Sq.in	Sq.in	T. C.	T. C.	T. C.	T. C.	T. C.		T. C.	T. C.
Joicey	1	1·2	2·3	Single Lp	Hand.	3·937by0·43	3·937by0·43	Two	1·03	0·994	0·994	15 0	17 18	18 0	18 2	....	Broke in the rivet holes of the punched seam	....	17 9½
do.	2	..	2·3	do.	do.	3·875by0·43	3·94 by 0·43	do.	0·883	1·021	1·032	15 0	....	15 0	15 1¾	....	Both plates of drilled seam broken, in former trial would not carry 15 tons..	....	14 11¼
do.	3	..	AA	do.	do.	2·05by0·38	2·05 by 0·38	One	0·515	0·470	0·470	12 0	....	12 0	....	23 6	Rivet sheared at once	....	....
do.	4	B B	..	do.	do.	do.	do.	do.	do.	do.	do.	8 0	8 13	8 15	....	16 19¾	Rivet sheared	18 12⅓	....
do.	5	C 1	C 2	do.	do.	do.	do.	do.	do.	do.	do.	8 0	9 10	9 13	21 6	18 14¾	Rivet broken, C 1 plate cracked in two places, and rivet head torn off C 2.	21 6	....
do.	6	D D	..	do.	do.	do.	do.	do.	do.	do.	do.	8 0	9 10	9 13	21 6	18 14¾	Rivet sheared, plate slightly cracked ..	21 6	....
do.	7	..	E E	do.	do.	do.	do.	do.	do.	do.	do.	8 0	8 5	8 8	....	16 6	Rivet sheared	17 17½	....
do.	8	F 1	F 2	do.	do.	do.	do.	do.	do.	do.	do.	8 0	8 8	8 10	....	16 10	Rivet sheared	18 1⅔	....
Boyd	9	C	..	do.	do.	3·9 by 0·39	3·9 by 0·37	Two	1·03	0·887	9·841	12 0	15 10	15 13	18 12	....	Broke through rivet holes in No. 2 plate	....	15 3¾
do.	10	..	D	do.	do.	3·9 by 0·40	3·9 by 0·37	do.	do.	0·910	0·841	12 0	16 3	16 5	17 17	....	Broke through rivet holes in No. 1 plate	....	15 15½
do.	11	E	..	do.	do.	3·9 by 0·38	3·9 by 0·38	do.	do.	0·864	0·864	12 0	14 10	14 13	16 19	....	Punched blind, broke through rivet holes	....	14 4⅓
do.	17	..	L	do.	do.	4·3 by 0·36	4·3 by 0·36	do.	do.	0·963	0·963	12 0	17 13	17 15	....	17 4⅔	One rivet sheared	18 8⅔	....
do.	18	..	M	do.	Mchn.	4·3 by 0·36	4·3 by 0·38	do.	do.	0·963	1·016	12 0	18 5	18 8	....	17 17¼	One rivet sheared	19 2	....

A paper was also read by Mr. Walter R. Browne, before the Institution of Mechanical Engineers, in January last, on the strength and proportions of rivetted joints, with the result of some recent experiments.

The Manufacture of Iron and Steel.—At a recent meeting of the Chemical Society, Mr. E. Riley read a paper on the manufacture of iron and steel.

The author, in his lecture, confined himself chiefly to the influence of the elements associated with iron in the pig, and the part they play in the subsequent conversion of the pig into wrought iron and steel; considering the present system of smelting in blast furnaces to be so simple that it was difficult to see how any process can compete with it, except in exceptional cases.

Although in certain districts there is not much variation in the pig made, the same ore and fuel being constantly used, yet in others, as in South Wales and Staffordshire, so many varieties of ore are employed that pig of all descriptions is produced. From the results of analyses of samples of Yorkshire cold-blast pig No. 1 to 6 iron) from the same works, it would appear that, whilst the phosphorus is almost constant in all the kinds, about 0·64 per cent., the quantity of sulphur decreases, and that of the silicon increases with the number. It is probable that the differences in the amount of sulphur present would explain the differences in the quality of the pig, for it is certain that sulphur makes grey iron into white. At the same time, however, the different numbers in grey iron may be produced by differences in the rate of cooling. The author criticised Mr. Bell's process for determining sulphur in iron, and gave details of the one he had himself employed. On examining the pigs of which the best wrought-iron is made, they will be found to contain silicon and phosphorus, Swedish iron, which contains no phosphorus and but little silicon, when used by itself giving a red-short iron. Hematite pig is special in its character on account of its freedom from phosphorus and its adaptability for the Bessemer process, although the amount of silicon present is not unfrequently as high as 4 or 5 per cent.

The chief constituents of pig-iron are carbon, silicon, sulphur, phosphorus, and manganese, traces of copper and titanium (the latter only in grey iron), frequently nickel and cobalt, and

occasionally vanadium and arsenic. The percentage of carbon in pig iron varies from 3 to 4 per cent., but the question as to whether it forms any definite compound with iron is open to great doubt. Mr. Snelus has shown that, by sifting out the finer portions from the borings of Middlesbrough pig, a material could be obtained containing 7·0 per cent. carbon, and by elutriation one containing more than 41 per cent. Sulphur seems always to be derived from the sulphide of iron that may be present in the fuel or ore, but from some experiments it would appear that an excess of lime may act on the sulphide of iron in the coke and convert it into sulphide of lime and metallic iron. Silicon is always present to a greater or less extent in iron, and the author has succeeded in obtaining an alloy of silicon and iron containing as much as 21·7 per cent. of the former. It is quite insoluble in hydrochloric acid, and only slightly acted on by *aqua regia*. With respect to phosphorus, practically speaking, all that is present in the ore and in the fuel used passes into the pig iron.

After some remarks on the comparatively little value of titanium as an ingredient in pig iron, the speaker discussed the quality and composition of the fuel employed in smelting, and then passed on to the process of refining. The time required for refining iron seems to depend on the amount of silicon present in the pig, much of it being separated during the operation and also some sulphur and phosphorus and a little carbon. The process of puddling was then described, and the merits of the various machines invented for that purpose discussed, with especial reference to the results obtained with that of Mr. Danks. The great advantage of machine puddling is the uniform quality of the wrought-iron made. In conclusion, the author made some remarks on steel, particularly with regard to the occurrence of silicon in it. This valuable and elaborate memoir was copiously illustrated with analyses.

Dormoy's Rotating Rabble—A paper was read at one of the recent meetings of the Society for the Encouragement of Arts, Manufactures, and Commerce, by Mr. F. Paget, on the use of a revolving rabble in the common puddling furnace. The paper described in more detail than was practicable when the same gentleman read his paper on that subject before the Institute, the mode of action of Dormoy's Rotating Rabble. It was

stated that the apparatus had been fitted up at the works of Messrs. Jeavons & Co., at Millwall, and that it had given good results. Mr. Jeavons afterwards expressed his satisfaction with the working of the apparatus, and stated that the machine might be seen in operation at the above-mentioned works.

Institution of Naval Architects.—The Institution of Naval Architects held their annual meeting on March 21st and following days. Several of the papers had an indirect bearing upon the industries represented in this JOURNAL. Mr. Scott read a paper on "A New System of Longitudinal Ship-building." Mr. T. S. Prideaux read a paper on "Economy of Fuel in Steamships." Captain J. Gordon M'Dakin also took up the same subject, together with a mode of burning the fuel in such a manner as to prevent smoke. Mr. F. J. Bramwell contributed a paper on "Quick Steam Launches," and Mr. George Seymour read a paper on "The Construction, Steering, and Propelling of Screw-steamers."

Construction of Ironworks.—At an ordinary meeting of the Cleveland Institution of Engineers, held in February last, Mr. E. Hutchinson, of the Skerne Iron Works, Darlington, read a paper upon the "Construction and Arrangement of Works for the Manufacture of Iron," of which the following is an abstract:—

After a few remarks on the subject of mechanical puddling, the author stated that one of the essentials in the arrangement of plant for iron-making was not only to provide for future extension, but also for a gradual substitution of mechanical appliances for manual labour, as well as for a constant replacement of more powerful or simpler machinery. The chief difficulty was that very few works were planned and built on an extensive scale, most being started in a small experimental way, so that some now turning out perhaps 1,500 tons of finished iron per week were originally intended for only a tenth of that quantity. He advocated that every works, to be economically and successfully managed, should be uniform in design, and constructed upon a plan agreed upon at the commencement. However, he thought that, owing to the very nature of the processes in the manufacture of iron, there was no possibility of their ever being conducted with the same degree of neatness and regularity which characterised many other branches of manufacture. Managers, too, experienced great difficulty in

endeavouring to use labour-saving apparatus, as the ironworkers, belonging chiefly to the lowest and least educated classes, lacked the intelligence to appreciate readily the merits of any tool or machine, and until these things were different, there was danger in attempting to do too much in the way of improving the arrangements of the works. It would be safer simply to imitate the neighbouring establishments, and to be satisfied if their works were as good as those, than to embark capital in machinery which the men could not or would not use. At present, owing to the incapacity of the men, or faulty engineering, the cost of repairing machinery was enormous, and would not be tolerated in any other department of industry. With a given amount of capital at his disposal, the adventurer in ironworks, had to consider first the extent of the operations he might be justified in attempting. He would be guided very much by the state of trade, how far it might be desirable to build more or less extensive, but more or less incomplete works; whether he should aim at a large output, without attempting to reduce the manufacturing cost to the lowest point, or be satisfied with a smaller make produced at a lower cost. Although, of course, large works should be managed more economically than small, the common fault at the outset was to attempt too much. In choosing a site for the works, the following desiderata, which were enumerated in the order of their supposed importance, would present themselves:—First—Proper rail or water communication, involving in most branches of the trade proximity to a good shipping port. Second—Supply of water suitable for boiler purposes. Third—Ground suitable for foundations. Fourth—Space, or means for disposing of ashes, slag, and rubbish. Fifth—An open, airy situation. Sixth—House accommodation for the workmen. Mr. Hutchinson remarked that the first and second points seldom escaped proper attention, nor was the third often altogether disregarded; but there were few works, old works especially, in which refuse materials were not felt to be a nuisance, and the cost of removing them a considerable addition to the making price. Many works, too, were so surrounded by buildings, or built on so low a level, as to be more or less unbearable for the workmen in warm weather, occasioning much inconvenience and loss of time. In other works, house accommodation in the neighbourhood was so defective, that considerable

permanent inducement, in the shape of extra pay, had to be held out to the workmen to induce them to put up with the attendant discomforts and expense. The most desirable situation, so far as the natural features of the site were concerned, would be on a slope of say—one in fifty, with rail communication on the high side, and a good extent of low ground in front for tipping ashes and rubbish. He would imagine, however, that the works were to be built on a dead level, and to occupy a rectangular piece of ground. The ground would be approached by railway at one end, by which the works would be supplied with all raw materials, and the finished iron despatched by the same means. The works would be laid out for rails, plates, bars, &c., and would produce from 1,800 to 2,000 tons of finished iron per week, not costing more than £240,000. To apply the old Staffordshire rule of £1,000 per puddling furnace, that would give 240 puddling furnaces, and all appliances for the finishing processes in connection therewith. It was now generally acknowledged, however, that this estimate was too low, and £1,200 per puddling furnace would be nearer the mark, whilst in most well-appointed works, a careful investigation of the cost account would perhaps result in a figure considerably in excess even of this. His estimate would be based upon £1,200 per furnace, giving 200 puddling furnaces, of which 60 might be applied to the rail mill, 50 to the plate mills, and so on. Mr. Hutchinson strongly recommended that the working floor should be elevated some $9\frac{1}{2}$ feet above the natural level of the ground, and that the boilers, engines, &c., should be as it were underground, which he showed had several advantages, the most important of which was that the ventilation of the works would be improved. His puddling furnaces would be arranged in four parallel straight lines, which system of placing possessed important advantages over the circular one, generally used at one time, with the shingling hammer in the centre. The supposed merits of the circular system were that all the furnaces were nearly equi-distant from the hammers, and each puddler could see what was going on at the hammer without leaving his furnace. However, he did not think it as good as the parallel system. The casings of the furnaces would be of malleable plate iron $\frac{3}{8}$ inch thick. He considered these preferable to cast iron ones, and he could not account how the latter were so generally adopted, as cast iron was more costly to

begin with, while from its inability to stand the variable strains upon it, it was liable to constant failure. In other respects his furnaces were of the ordinary kind. He then discussed the relative merits of boiler and common stack furnaces. He said it was the opinion of many persons that no economy attended the employment of the waste heat of the puddling and mill furnaces, as the saving of coal, otherwise consumed in the fired boilers, was more than counterbalanced by the extra quantity consumed in the furnaces themselves. Boiler furnaces were also a permanent source of considerable danger to the men themselves. Puddling furnaces of the old kind, with independent brickwork stacks, mostly worked to greater advantage, he thought, than those connected with boilers. The boilers the author proposed to use would be quite out of the way, and in the best position for avoiding loss of heat and condensation of steam by radiation, whilst they would be, if anything, less dangerously situated than boilers standing vertically at a considerable height above the floor. They would be so arranged as to come in contact with the brickwork only where the flues connected themselves with the tubes of the boiler, and ample room would be left all round the boiler for external examination. When at work the space enclosed would be completely closed in, so as to be surrounded by an atmosphere of heated air. The roof of the space would be formed of cast iron plates, covered with sand to a thickness of nine or ten inches. In the event of a boiler needing repairs, the flue communicating with the puddling furnace would be bricked up, and the damper, giving direct opening to the main flue, would be used, the furnaces being kept going independently of the boiler. There would be two furnaces to each boiler, and half the furnaces would not work with boilers at all, so that the waste heat from these might, if thought desirable, be used for raising the temperature of the draught air before it reached the fire grate. The boilers would be twenty feet long and four feet nine inches in diameter, the internal flue tubes being strengthened, and the heating surface increased in area, by the introduction of a sufficient number of Galloway's tubes. On each side of the row of boilers, and directly under each row of puddling furnaces, the author would have open passages, running from end to end of the row of puddling furnaces. These passages or tunnels would be five feet wide, and seven feet high, and were intended to serve the

double purpose of affording access to the boiler mountings, and of ventilating the forge. The passages would be arched over with brickwork, except at the centre of each boiler, where more head-room was required, to enable the boiler attendant to get at the valves and fittings. The boilers would work at 45lbs. per square inch pressure of steam, but the engines, hammers, &c., would be designed to do full duty at 30lbs. as a minimum pressure, it being almost impossible to avoid great fluctuations in pressure in furnace-heated boilers. The shingling hammer would not be placed so near the rolls as was now the case, and would be in the proportion of one hammer to 12 furnaces. One hammer was frequently shingling for 25 furnaces at present, but failures of the piston rods, &c., were of such frequent occurrence that the shingling power, he considered, ought to be at least 25 per cent. in excess of that of the puddling to ensure full work. It should also exceed the rolling power by 10 or 12 per cent. The hammer foundations would be left exposed, and accessible at all times. The author thought that single acting hand-worked hammers gave less trouble than double acting ones. The form of forge engine would be of the direct acting kind, fixed to a strong diagonal frame. The engine, no part of which should project above the working-floor, except the crank and shaft, would have 30 inches diameter of cylinder, with a stroke of 4 feet 6 inches. The fly-wheel would be 22 feet in diameter, and weighing 35 tons, making thirty revolutions per minute. Geared engines were now mostly out of fashion. It was, he asserted, now pretty generally allowed to be a bad plan to drive two mills by the same engine, or to run more than three pairs of rolls in a train. In some cases reversing gear had been applied to forge trains, without any experience of reversing forge trains. He would, however, question their merits. The conditions, rendering their use so advantageous in plate and other heavy mills, seemed to be wanting in the forge. There was little or no danger of a puddled bloom becoming so cold that it could not be rolled down to its proper thickness, and the masses of material were of such a weight, and in so convenient a form for handling, that it was difficult to see how any appreciable saving in labour would be effected by the reversing process; whilst, as the capabilities of a pair of rolls were limited only by their temperature when at work, it was not practicable to work with many fewer or smaller rolls

than under the ordinary system. The top roll, however, should be well balanced, and with a free lift of 7 or 8 inches, so as to be capable of dealing with Mr. Danks's blooms, whenever they might come. The forge rolls would be 22 inches in diameter. For facilitating the more laborious operations connected with heavier mills, various appliances had, during the last few years, been designed. In plate mills, and those, generally, not running at a speed of 30 revolutions or so per minute, reversing gear was now of almost universal adoption. Where a fly-wheel was used, the simplest plan was to reverse by means of a clutch on the main-shaft, sliding between two spur wheels, driven in opposite directions. The clutch might be worked either by hand or steam power, and should be made in segments, so that it could be replaced readily without lifting the shaft, and the claws should be armed with loose steel face pieces, which could, when worn, be changed in a few minutes. The roof of the forge would be in three bays, the two outer ones being of 36 feet span, and the centre one of 53 feet. The roof over the forge rolls and finishing mills would be in five bays, the two outer ones being of 36 feet span, and the three inner ones of 53 feet. Ventilators would run from end to end of each bay of roofing. The supporting columns of the roof are spaced on an average of 18 feet centres; but in the forge the distance is modified somewhat, so as to bring the columns close to the puddling furnaces.

NOTES ON

THE BRITISH IRON AND STEEL TRADES.

Danks's Rotary Puddling Furnace.—In accordance with arrangements made at the annual meeting in March, the members of the Institute were invited to Middlesbrough, on April 5th, by Mr. W. R. I. Hopkins, on behalf of Messrs. Hopkins, Gilkes, & Co., and on that occasion, the Danks furnace, erected by the above-named firm, was shown in operation.

Robertson's Squeezer.—Mr. Robertson, of Glasgow, has designed a form of squeezer, which is meant to manipulate large masses of puddled iron, and to reduce the same to a bloom of the required size. The apparatus consists essentially of two truncated cones fluted longitudinally, and made to revolve in such a manner that the material to be operated upon is not only subjected to a rapid compressing action, but is gradually carried forward, and is delivered from the rolls in a cylindrical form. It is asserted that by this form of squeezer it will be practicable to make blooms of different dimensions, by the introduction of an arrangement for varying the inclination of the revolving rollers.

International Exhibition.—In the series of London International Exhibitions that have been organised, it will be several years before iron and steel come in for special illustration. This year, matters of interest to these industries are shown, but most of them are already familiar to the trade. Mr. Head, Middlesbrough, exhibits a new form of governor, described by him at the meeting of Mechanical Engineers, held in Cleveland last year. He has also a series of drawings, illustrating the Newport furnace. Mr Thos. Whitwell contributes a large model of his fire-brick stove. Mr. Danks has a model of his rotary furnace. The Eagle Iron Co., West Bromwich, have a case of specimens of iron manufactured at their works.

Geological Survey.—Prof. Ramsay, F.R.S., has been appointed the successor to the late Sir Roderick Murchison, as Director-General of the Geological Survey for Great Britain and Ireland. Mr. Bristow has succeeded Mr. Ramsay as Local Director for England.

Napier's Differential Clutch.—Mr. Napier, of Glasgow, has applied his differential clutch to a reversing mill at the works of the Butterley Iron Company, Derbyshire. The results are reported to be highly satisfactory. The arrangement will be fully described by Mr. Napier at the next meeting of the Institute.

Production of Pig Iron in Cleveland.—The Ironmasters' Association of Cleveland have published the following as the make of iron in that district for the four months ending 30th April:—

	1872. Tons.	1871. Tons.
January	160,567	151,826
February	155,672	141,068
March	168,685	161,049
April	163,408	155,472
	648,332	609,415

Henderson's Process for Purifying Iron.—The inventor claims that, by his process, phosphorus may as a rule be removed from all kinds of mine pig iron in sufficient amount to render the iron pure enough for steel. At a trial made at the Blochairn Iron Works, Glasgow, on 23rd December last, No. 4 Dálmellington pig iron was treated, and the analyses of pig iron, by Mr. Edward Riley, are as follows:—

Pig Iron, phosphorus per cent.	1·14
Refined Cast Iron 30 mins. after fusion	0·23
„ „ 40 „ „	0·15
„ „ 50 „ „	0·12
Wrought iron	0·07
The cinder	0·52

360 lbs. pig iron, 100 lbs. ilmenite, 10 lbs. manganese, and 42 lbs. of fluoride of calcium were used.

The complete analysis of the cinder is—

	Per Cent.
Silica	11·12
Titanic acid	5·02
Protoxide of iron	56·41
Peroxide of iron	18·20
Alumina	1·73
Protoxide of manganese ...	2·22
Lime	3·51
Magnesia	0·43
Phosphoric acid...	1·19*
Sulphur	0·09
Nickel	trace
	99·92
Metallic iron	56·62

*=0·25 per cent. phosphorus.

The pig iron, smelted from cinder of the above composition, will contain all the phosphorus in the cinder, which will be 0·87 per cent. in the pig iron, or 0·27 per cent. less than the original pig iron smelted from ore. As the phosphorus is not all in the cinder that was removed from the iron, the remainder must have become volatilised.

Midland Steam Boiler Inspection and Assurance Company.—The last report states that the list of boilers under the care of the Company was:—Southern division, 2,084; Northern district, 961; total, 3,044. Of these, 1,743 are under insurance, and 1,301 under inspection only. The number of boilers connected with collieries and mines is 1,174, and in connection with ironworks, 1,451. The chief engineer reports that during last year 66 explosions occurred throughout the country.

Water Screens for Puddling Furnaces.—It is reported that Russell's Water Screens for puddling and heating furnaces, as adopted at the Forest Vale Iron Works, Cuiderford, Gloucestershire, are very much liked by the workmen. The object of the invention is to protect and screen the puddlers and workmen from the heat of the furnace This is accomplished by combining with the furnace, screens of wrought or cast iron, supported parallel to, and at a short distance from, the front of the furnace to which the invention is applied. Two of the screens cover the front of the furnace on either side of the puddling door, whilst the middle screen nearly covers the furnace door, leaving a hole exposed. The screens are kept cool by jets of water thrown upon the outer sides. The water, after it reaches the bottom of the screens, is conducted away by

suitable troughs. The screens can readily be disconnected from the furnaces.

Manchester Steam Users' Association.—This society, in the last annual report, states that it has more boilers under inspection than at any previous period. No explosion had occurred during the year at a boiler under the care of the Association.

Litho-fracteur.—At the instance of the War Office Commission on explosive substances, a number of experiments have been made at the Nantmawr quarries, near Shrewsbury. When lighted in the air, this substance burns slowly, but when fired with a percussion tube, it explodes with great violence. The experiments demonstrated that this is a very valuable explosive material.

New Iron Companies.—Since the commencement of the year, a large number of new iron companies have been formed. The following is a list. Those marked with an asterisk have been brought out in England, but the operations of the companies will be mainly carried on abroad.

	Capital.
Castle Dykes Iron	£80,000
Lydney and Wigpool Iron Ore ...	150,000
Wensleydale Iron	60,000
Bedworth Coal and Iron	100,000
Whitehaven Iron Mines	20,000
*Spanish Hematite Iron	75,000
ultimately	150,000
Abergavenny Iron and Tin-plate ...	25,000
Erewash Valley Iron	20,000
Antrim Iron Ore	100,000
South Cleveland Iron Works... ...	200,000
Mowbray Iron Ore	20,000
*Malaga Magnetic Iron Ore	175,000
*Central Swedish Iron and Steel ...	325,000
Castle Hill Iron Mining	10,000
Highfield Hematite Iron Ore... ...	40,000
Trimsaran Coal, Iron, and Steel ...	100,000
Evishacrow Iron Ore	80,000
Welsh Freehold Coal and Iron ...	155,000
Co-operative Iron Works	20,000
Coleford Hematite Iron	100,000
Chillington Iron	350,000
Millsands Rolling Mills	100,000
Llynvi, Tondu, and Ogmore	550,000
Outwood Iron...	30,000

Exports of IRON and STEEL during the four months ending April 30th, 1872, compared with those for the corresponding periods of 1870 and 1871:—

IRON.

	Countries to which Exported.	1870. Tons.	1871. Tons.	1872. Tons.
PIG	To Germany	31,925	36,215	73,466
	,, Holland	44,562	51,894	98,113
	,, France	47,094	11,866	37,725
	,, United States	28,287	54,449	61,483
	,, Other Countries	85,114	83,298	111,598
	Total	236,982	237,722	382,385
BAR, ANGLE, BOLT, AND ROD	To Germany	3,554	3,339	5,102
	,, Holland	3,874	2,332	3,003
	,, France	3,228	70	331
	,, Italy	12,567	10,286	8,175
	,, Turkey	4,332	2,512	3,333
	,, United States	12,789	15,870	25,928
	,, British North America	12,235	10,906	12,022
	,, ,, India	11,729	8,022	5,881
	,, Australia	4,782	2,849	5,566
	,, Other Countries	30,288	27,815	32,487
	Total	99,378	84,001	101,828
RAILROAD OF ALL SORTS	To Russia	24,725	14,732	3,877
	,, Sweden	—	1,213	5,009
	,, Germany	14,299	20,164	9,741
	,, Holland	7,235	1,688	1,787
	,, France	146	1,030	61
	,, Spain and Canaries	7,328	3,413	4,972
	,, Austrian Territories	13,563	609	3,827
	,, Egypt	1,521	446	8,578
	,, United States	117,805	135,421	180,193
	,, Spanish West India Islands	1,614	533	633
	,, Brazil	1,933	6,237	6,411
	,, Peru	2,932	5,537	12,324
	,, Chili	5,704	909	814
	,, British North America	8,704	8,636	10,242
	,, ,, India	73,681	21,672	2,723
	,, Australia	4,417	7,917	6,206
	,, Other Countries	20,420	21,985	21,863
	Total	306,027	252,142	279,261
WIRE OF IRON OR STEEL (except Telegraph Wire) galvanised or not		7,720	7,131	10,485
HOOPS, SHEETS, AND BOILER & ARMOUR PLATES	To Russia	888	2,088	1,758
	,, Germany	3,863	2,458	3,748
	,, Holland	2,174	2,212	2,648
	,, France	1,892	171	1,215
	,, Spain and Canaries	1,577	1,580	1,709
	,, United States	9,995	10,430	9,524
	,, British North America	2,826	2,647	2,673
	,, ,, India	6,576	4,468	7,694
	,, Australia	4,760	4,330	5,385
	,, Other Countries	18,057	17,190	24,438
	Total	52,608	47,574	60,792

		Cwts.	Cwts.	Cwts.
TIN PLATES ...	To France	15,392	6,229	24,257
	,, United States	464,497	526,562	626,717
	,, British North America...	12,214	14,148	17,251
	,, Australia...	16,242	32,728	31,541
	,, Other Countries... ...	108,534	115,937	116,831
	Total	616,879	695,604	816,597

		Tons.	Tons.	Tons.
CAST OR WROUGHT AND ALL OTHER MANUFACTURES (EXCEPT ORDNANCE UNENUMERATED)...	To Russia	1,336	3,287	1,627
	,, Germany	5,451	5,969	6,913
	,, Holland	1,737	1,940	5,272
	,, France	1,882	1,210	1,552
	,, Spain and Canaries ...	2,937	1,292	2,604
	,, United States	2,734	3,173	4,549
	,, British North America...	3,443	3,474	5,374
	,, ,, Possessions in South Africa	575	752	998
	,, India	8,850	12,682	7,438
	,, Australia	6,082	4,634	5,811
	,, Other Countries... ...	31,644	28,991	35,716
	Total	66,671	67,404	77,854
IRON, Old, for re-manufacture		31,538	32,426	27,723

STEEL, UNWROUGHT.

To France	1,143	127	1,034
,, United States	4,440	5,512	7,917
,, Other Countries ...	4,208	3,274	4,797
Total	9,791	8,913	13,748
MANUFACTURE OF STEEL OR STEEL AND IRON combined	3,236	3,444	3,161
TOTAL OF IRON AND STEEL	844,794	775,537	998,067